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OPTICAL DEFECTS

AMONG THE OFFICERS AND MEN ALREADY ENGAGED
IN THEM.

BY

SURGEON-GENERAL T. LONGMORE, C.B.,

HONORARY SURGEON TO THE QUEEN;
PROFESSOR OF MILITARY SURGERY AT THE ARMY MEDICAL SCHOOL;
OFFICER OF THE LEGION OF HONOUR;
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PREFACE TO THE THIRD EDITION.

The circumstances under which I was led to put forth this Manual of Instructions for testing and dealing with the various conditions of vision liable to be met with in persons seeking employment, or already engaged, in military service, have been explained in the two previous editions of this work, which were published in the years 1862 and 1874, and do not require repetition. Since the second edition of the Manual was published, so great have been the changes in some of the practical parts of optical manipulation, and such advances have been made in respect to length of range, and capacity for accurate fire, in the weapons which soldiers now have to deal with, that many passages of the Manual of that date have become obsolete, and the present edition has had to be less revised than re-written.

When the increased and increasing importance attached to men becoming experts in the use of firearms of all descriptions at very long ranges is remembered, it may reasonably be expected that before long even greater attention will be given by all persons in this country who are engaged in military pursuits to questions of quality of eyesight, and that more information will be demanded on the subject from medical officers than has hitherto been required from them. In the army, the firearm with which the infantry soldier has to become familiar is his rifle, and this is an instrument which in practice he can only use with thorough efficiency when he has visual power enough to enable him to see clearly the objects which he is required to aim at, and to form an accurate judgment of their distances, whatever may be the range over which the projectile discharged from it has to pass. A great deal of attention has been given of late years to improving the modes of instruction in musketry practice, and very recently important changes have been made in it, with a view to insure perfection, not so much in hitting a definite mark on a target, as to ensure accuracy of aim under conditions similar to those which are likely to occur when the soldier is engaged actively in the field; but whatever may be the mode of instruction, so long as the rifle is such as it is, and objects of limited sizes, such as men, are to be fired at from distances of eight or nine hundred yards and upwards, an adequate power of eyesight must evidently be the prime ingredient necessary to ensure the success of the marksman. The more this fact is appreciated, the more the importance will be felt of giving attention to the subject of the quality of eyesight of every one who aspires to effective employment of a rifle. It hardly seems too much to anticipate that, in respect to army service, at some future time the visual quality of every recruit will be as much recorded on his entry into the army as his height, chest measurement, weight, or any other of his physical conditions which are now registered; for some of them, considering all the sanitary precautions and personal care that are now taken to preserve the physical efficiency and good health of the soldier, have lost much of the importance that belonged to them in former days, and can hardly be regarded as equal in value to the amount of visual power which the man possesses, so far as his usefulness during the period he is engaged on active service is concerned. Military efficiency, the personal safety of troops, and economy of expenditure of ammunition, are all involved in the capacity of soldiers for making an accurate use of the firearms placed in their hands. It is certain that the capabilities of the rifle can only be completely turned to account by persons who possess normal acuteness of vision, at least as regards the right eye, and it seems to be manifestly important, therefore, that the qualifications of each man who is destined to be a rifleman should be thoroughly known on his starting in the service; so that, on the one hand, the time and efforts of instructors may not be wasted in trying to teach men matters which from natural causes they may be totally incompetent to acquire, whatever labour may be devoted by themselves or others to the attempt, and also, on the other hand, that the men may be distinguished and made known to commanding officers, who possess the necessary optical qualities for becoming sure and reliable marksmen.

Not improbably as further advances are made in musketry instruction, a greater influence will be exerted by physiological optics on certain parts of the teaching. The objects painted on targets and employed in "educating" men in the use of the rifle at the various range practices have not been designed, as shown in the text, on an uniform visual standard, but seem rather to have been settled, especially as regards their dimensions at the various distances at which they are usually placed for firing practice, according to the proportions which have been considered, from personal observation, to be the most suitable for marks to be aimed at. There is apparently no sufficient reason why all such objects should not be fashioned on a regularly graduated scale of dimensions and configuration in relation to distance, and be in exact accordance with the optical conditions, so far as the objects themselves are concerned, under which they would present themselves as marks to be fired at in actual warfare. If a series of objects on such principles should be brought into use, the quality of sight necessary for a satisfactory execution of the contemplated task at any particular range of practice could be defined with almost mathematical precision.

Medical officers at present only have to determine the question whether a man is optically fit for military service so far as the possession of a set minimum standard of vision is concerned ; but in performing the duties of recruiting, they may have in the future to answer several questions of a more complex kind. They may be required to furnish information on such questions as the following : Is the man visually qualified to become a marksman up to the longest range for which the rifle is capable of adjustment? If not fit for a complete marksman, up to which class of practice does his visual power admit of the man being advantageously trained? If not fit for the use of an arm of precision in the first line of the army, is he fit for duty in the ranks of the Militia or Volunteer forces? If not fit for the duties of a rifleman, is he visually qualified for service in the Commissariat and Transport, or for any other corps or department of the army? After a sufficient number of records on these subjects have been accumulated, a conclusion may be arrived at on certain questions, which are regarded under different aspects in different armies, and which may well admit of different solutions in different countries ; as, for example, whether the proportion of men in this country, whose sharpness of sight is inferior to the normal standard owing to refractive defects, is so great as to render it advisable, from a military and financial point of view, to allow correcting spectacles to be used in the ranks of the army? and, in case of a decision being come to that it is advisable, whether the permission to wear them should be restricted to spectacles of certain descriptions, and if so, of what descriptions?

I do not think it too much to assert that an acquaintance with the subjects described in this Manual, combined with a moderate amount of practice, will enable medical officers to furnish satisfactory. information, when required, on the various points to which I have alluded, as well as on any others of a similar nature that may arise, and to carry out any orders that may be issued in respect to visual examination, or to correction of ocular defects among the officers and men of the army, in all ordinary cases which depend on faults of refraction or accommodation. At the same time it should not be forgotten that under the usual circumstances of service, in consequence of the multitudinous duties which devolve on medical officers, it would be too much to expect that more than a limited number among them will find the time or opportunities for becoming experts in ocular investigations. Arrangements will probably still have to be made, as hitherto, for complicated and doubtful cases of defective vision to be sent to general hospitals, and referred to medical officers who have acquired a particular acquaintance with the visual conditions which are liable to be encountered, by having had the means of carrying out extended observations of them at such institutions, and where also there will generally be the opportunity of using special optical appliances, which cannot be expected to be found at more limited establishments.

Athough the metrical system of numeration of lenses and of measurement in general is now ordinarily employed by ophthalmic surgeons, and is no doubt destined to supersede the duodecimal system everywhere, there are still many practical difficulties in the way of its adoption by British military medical officers in the different parts of the world in which they have to perform their duties. They have not, as a rule, cases of lenses numbered in dioptrics available for their use; the ordinary appliances for measurement at their command are divided by inches; and these will probably remain the conditions in respect to such matters until the metre becomes the standard of measurement for the ordinary purposes of society and commerce. It thus becomes necessary for British medical officers to be acquainted with both systems of measurement, and to be able to convert readily the expressions in the metrical system which they meet with in scientific works, into their relative values on the duodecimal system. The means of doing this are fully explained in this Manual, and where references are made to optical measurements in the body of the work, they are usually stated in figures belonging to both the metrical and duodecimal systems of measurement.

In the former editions of this work, a second part was devoted to a description of the ophthalmoscopic appearances and diagnostic signs of the principal morbid states liable to be met with in the structures within the ocular cavity. This part is omitted in the present edition, because the Treatises and Manuals in which these diseased conditions are described are now very numerous, and also because in many instances they have the advantage of being accompanied by illustrative drawings, which are of special value to all those who are engaged in a study of such subjects. The present work is, therefore, now limited to a study, theoretical and practical, of those varieties of the visual function, which for the most part are independent of morbid processes, and in considering these conditions of sight, their bearing on military service is always kept in view. I have at the same time added short explanations on a variety of optical matters more or less directly connected with visual examination and the correction of visual defects, a knowledge of which is essential to a right understanding of the principles on which the practical part of the work is conducted. Experience in teaching the modes of conducting the visual examination of recruits and soldiers, and the practical correction of visual defects, has proved to me the need of such information being given, and I hope that some of the explanations and matters of fact, which it has been found necessary to impart in the course of instruction at the Army Medical School, may prove to be serviceable as memoranda to medical officers in the larger sphere of the Army Medical Department itself.

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THE OPTICAL MANUAL.

CHAPTER I.

Preliminary Remarks.—Optical Memoranda.—Normal Vision.—Monocular Vision.—Binocular Vision.—Double Vision.—Optic Axis.—Visual Axis.—Radiation of Light.—Permeability of Bodies to Light.—Reflection of Light.—Refraction.—Law of Visible Direction.—Inversion of Images on the Retina.—Visual Angle.—Field of Vision.—Monocular and Binocular Fields of Vision.—Their Measurement.—Movements of the Eye.—Field of View.—Objects on the Visual Field.—Brightness of Objects at different Distances.—Motion of Objects in the Visual Field.—Judging Distance.—Aiming.—Monocular Aim.—Strengthening Sight for Long Ranges.—Infinite Rays.—Lenses.—Convex and Concave Lenses.—Numeration of Lenses.—Duodecimal and Metrical Systems.—Comparison of the two Systems.—Metrical Lenses and their Values in English inches.—Cylindrical Lenses, their Varieties and Actions.—Trial case of Lenses.—Mode of Testing the Power of a Convex, Concave, or Cylindrical Lens.—Army Optical and Ophthalmoscopic Case.—Images formed by Lenses.—Composition of Lenses.—Spectacles.—Eyeglasses.—Equi-convex and Equi-concave Lenses for Spectacles.—Pantoscopic, Periscopic, Orthoscopic, Duplex Focal, and Tinted Lenses for Spectacles.—Eye Protectors, Goggles.—Prismatic Spectacles.—Stenopœic Hole and Stenopœic Slit.—Stenopœic Spectacles.—Strabometer.—Prisms for Ophthalmic Purposes.—Abbreviations.—Symbols.

Preliminary Remarks.—The chief purpose of this manual is to furnish medical officers with such memoranda as will assist them in ascertaining the quality and power of vision of recruits and soldiers, and in pronouncing an opinion on their fitness, so far as sight is concerned, for military service. It is necessary therefore, to describe the various qualities of vision which are liable to be met with. The chief characteristics of the different conditions of sight depending upon differences in the refractive power and conformation of the eye, and the modes of determining the degrees in which these differences exist, will be treated on in the second chapter; while other states of vision, either associated with them, or occasionally consequent upon them, will be remarked upon in succeeding chapters. The visual needs of men employed in the different branches of the military services, army and navy, the regulations concerning the degrees of defective vision which disqualify men for occupation in them, and the means employed for detecting and estimating them will be fully described subsequently.

In carrying out practical instruction on the optical examination of the eye at the Army Medical School, it has been constantly found necessary to explain some elementary matters on optics which must be known before the phenomena of vision, whether normal or abnormal, or the principles on which refractive and accommodatory defects of vision are corrected, or the means by which the correction is effected, can be properly understood. Several parts of the special work of soldiers, on which quality of vision exerts a material influence, such as the practice of judging distances of objects, of aiming at long ranges, and others, also require some preliminary explanations to be given to those who have not previously had to consider such subjects. The chief of these optical memoranda and allied topics are given in this introductory chapter in as plain and concise a form as possible for convenience of reference.

Vision.—Normal vision exists when, firstly, each eye is so constructed that a sharp and exact image of the object toward which the eye is directed, is formed upon the proper sentient layer of its retina; and when, secondly, a correct appreciation of the form, position, colour, and most of the physical qualities of the object so depicted is conveyed to the mind. To effect the first of these conditions, the curvatures, refractive qualities, and mutual relations of the transparent media of each eye must be such, that the rays of light proceeding from the external object are all brought by them to suitable foci upon corresponding points of the percipient retinæ. To effect the second of these conditions, the images must be of sufficient size, sufficiently but not excessively illuminated, and must remain sufficiently long on the retinæ; the expanded retinæ and their component layers, the optic nerves and their cerebral connexions, must be healthy; the mutual relations of accommodation to distance, and of direction of the visual lines must be in normal accord; and the perceptive faculties must have been duly educated.

Monocular Vision.—Vision by one eye. An object, though solid, when looked at by one eye, the other being closed, appears as a plane figure, having two dimensions, viz., length and breadth. When a group of objects is regarded monocularly, although the lights and shadows among them are visible, there is no sense of their relative distances or depths. These defects of monocular vision may to a certain extent be counteracted by long practice and training, but the effects of binocular vision can never be fully realized by the use of one eye alone.

Binocular Vision.—Single vision by two eyes. The visual lines, or lines prolonged from the fovea centralis and passing through the nodal point of each eye, meet in the same point of an object. If the object be solid, the images of it, or rather of such portions of them as are common to the two eyes, are formed on exactly corresponding parts of the two retinæ. Images of certain parts of the solid object are only formed in each eye singly,—in the eye on the same side as the parts concerned. Under these conditions the solid object appears as a figure having three dimensions, viz., length, breadth, and thickness, and perception of *relief* is obtained.

A wider field and range of vision are obtained with two eyes than with a single eye. The double impression on the two retinæ in binocular vision also causes the perception of objects to be more intense than it is in monocular vision. Owing to the visual perception being thus intensified, the rapidity with which objects are recognised, or visual alertness, is increased under binocular vision. The greater or less degree of convergence of the visual lines which accompanies binocular vision also helps the observer to form ideas of the distances at which the different objects looked at are situated. It is obvious that, as regards near objects which are situated in the median plane between the two eyes of an observer, the convergence of the two eyes must be in exact accord in order to ensure perfect singleness of vision of these objects.

Diplopia.—Double vision. This results when an object is perceived by both eyes, but its two images are not formed on corresponding points of the two retinæ. The visual lines of the two eyes do not meet and join each other in the object. When the separate images correspond in their relative positions with the relative positions of the two eyes, they are described as *homonymous;* when on the contrary, the image to the left in position belongs to the right eye, and that to the right is the image perceived by the left eye, they are spoken of as *crossed images.*

Optic Axis.—A line prolonged from the centre of the cornea, through the nodal point of the eye, to the retina. The posterior pole of the optic axis impinges on the retina a little to the inner side of the fovea centralis.

Visual Axis, or visual line.—The line along which the axial ray proceeding from the point of the object looked at passes to terminate in the fovea centralis. In the emmetropic eye it enters a little to the inner side of the centre of the cornea, crosses the optic axis at the nodal point, and falls on the fovea centralis ; or *vice versâ*, starts from the fovea centralis, and passing through the nodal point, terminates in the object looked at. The visual line thus forms an angle with the optic axis, the apex of which is at the nodal point of the eye ; the size of this angle varies in different eyes according to their refractive qualities, whether emmetropic, myopic, or hypermetropic.

In binocular vision, when the object which is viewed is remote, the visual lines of the two eyes are parallel, or nearly parallel, with each other ; in proportion as the object viewed approaches nearer to the observer, the visual lines from the two eyes necessarily become more and more convergent in direction.

Radiation of Light.—The expression *ray of light* indicates the straight line along which light is transmitted, and the term *radiation* signifies the transmission of rays in all directions from a luminous point. A collection of rays so disseminated from a luminous point as to assume a conical outline, is called a diverging *pencil of rays;* and the apex of the cone from which they proceed is called the *focus* of the pencil. So also, when rays are artificially caused to converge to a common point, they are together spoken of as a converging pencil of rays ; and the point at which they all meet is called the focus.

The illuminated surface of any object, in respect to the light it is receiving, is regarded as lighted by the bases of a number of divergent pencils of rays, whose foci are at the source of illumination ; and, in respect to the light it is imparting by reflection from its surface, by means of which it is rendered visible, it is regarded as composed of an infinite number of luminous points, which points are the foci of a corresponding number of diverging pencils of rays. It is important, when speaking of the rays proceeding from an illuminated object, not to confound the rays emanating from two points remote from each other (as from the extreme points between which the visual angle is included, for example) with the rays proceeding from each luminous point of the object independently.

Permeability of Bodies to Light.—All substances are probably pervious to light in different degrees and to different depths. If the substance be one which allows no rays of light to pass through it, it is said to be *opaque;* if it be one which admits of light passing completely through it, or nearly so, it is termed *transparent. Shadows* result from opaque bodies intercepting the passage of light. All bodies, whether opaque or transparent, vary in aspect and colour according as they vary in reflecting, absorbing, or decomposing the light which falls on them.

Reflection of Light.—All bodies, whether opaque or transparent, with smoothly polished surfaces, under certain conditions turn away the rays of light which fall on them from their original direction. This is termed *reflection of light.* There are two general laws of reflection of light. The first is that whatever may be the angle which a ray impinging on a polished surface forms with the normal, or perpendicular, to that surface, the angle at which it is turned away from that normal will be the same; in other words the *angle of reflection* is equal to the *angle of incidence*, and on the opposite side of the normal. The second law is that the plane in which the incident ray is found will be the same as the plane in which the reflected ray is found, or in other words, the *plane of incidence* coincides with the *plane of reflection.* All the phenomena of reflection of rays of light from polished surfaces, whether plane or curved, take place in accordance with these laws. If the polished surface be either level, or have a regular curvature, the reflected rays of light produce images of the objects from which the rays have proceeded. If the surface be roughened, there will still be reflection of light, but the reflected rays are irregularly dispersed and no images are produced.

Refraction of Light.—Rays of light proceed in straight lines so long as the medium through which they are travelling is of uniform density. Where a ray passes obliquely from a rarer into a denser medium it is bent or *refracted towards* a line drawn perpendicularly to the surface of this medium at the point of incidence; conversely, on passing obliquely from a denser into a rarer medium, it is *refracted from* a line drawn perpendicularly to its surface. This change of direction commences at the surface of separation of the two media. If a ray of light passes through media of different densities *perpendicularly* to the surfaces where these media are in contact with one another, the ray travels onwards in one and the same straight line. The deviation of rays of light from their original direction on passing obliquely from one into another medium of different density takes place according to fixed laws, and the investigation of these laws, and of the phenomena which result from them, constitute the branch of optics generally termed *dioptrics*. The three following laws are constant in all cases of refraction. (1.) The angle formed by an incident ray of light with the perpendicular to the surface, *or the angle of incidence*, and the angle formed by the refracted ray with the perpendicular, *or the angle of refraction*, are in the same plane. (2.) The incident ray and the refracted ray are always on opposite sides of the perpendicular. (3.) Whatever the inclination of the incident ray to the surface, the sine of the angle of incidence has a constant ratio to the sine of the angle of refraction. These laws apply to curved surfaces equally with plane surfaces, and hence, when the form of surface and nature of a refracting medium are known, the path of any refracted ray can always be determined.

Law of Visible Direction.—Each point of an object is seen in a line perpendicular, or nearly so, to the point of the retina which its image impinges.

Inversion of Images on the Retina.—The pictures formed on the retina of external objects are *inverted* and *curved*, owing to the action of the optical apparatus of the eye, together with the concave form of the retinal receiving surface. The mind, however, does not judge of the positions of objects, whether primary or reflected, according to the part of the retina on which their images happen to fall; if it did, the positions of things would appear to change with changes in the position of the eyes looking at them. But the mind judges of the positions of objects by following, as it were, the directions of the axial rays proceeding to all the points of these objects from the parts of the retina on which the corresponding images of such points are pictured. Hence, though the images of objects looked at directly are inverted on the retina by the action of the refracting media of the eye, the mind, following the lines of light to their sources in accordance with the law of visible direction, sees them in their true positions. The images of objects below the level of the visual diameter are pictured in the upper retinal hemisphere; the images of objects above this line in the lower retinal hemisphere; they are equally reversed in the lateral portions of the retinal picture; but, nevertheless, all the objects are seen in their real positions and relations to each other. This equally applies to the reflected images of real objects: the reflected images are inverted on the retina, but they are seen truly in the forms in which they proceed from the reflecting surface.

Visual Angle.—The visual angle is the angle included between two rays proceeding from the opposite extreme limits of an object looked at by the eye and meeting at a point within the eye. These rays, having met, cross each other and pass onward to assist in forming the image on the retina. The point at which they meet is known as "the point of intersection," or "nodal point," of the eye. The size of the angle depends on the actual linear dimensions of an object, and on the distance of the object from the eye. If the object be of a fixed size, the size of the angle under which it is seen will vary inversely as its distance from the eye ; if the distance be fixed, the size of the visual angle will vary in a *direct* ratio with the size of the object. The angle is similar on each side of the point of intersection—towards the object, the "visual angle," and towards the image of it on the retina, the "retinal angle." The expression that an object occupies so many degrees in the circumference of a circle of which the eye is the centre, or that it subtends an angle of so many degrees, has the same significance as "the size of the visual angle of the object."

The size of the image of an object formed on the retina varies as the retinal angle, and therefore as the visual angle varies under which the object is seen. The larger the visual angle, the larger the retinal image. If the size of an object remain the same, the visual angle it subtends is increased in proportion as it is brought nearer to the eye ; and hence, the frequently observed approximation of printed letters by Hc. patients to their eyes, although the diffusion of rays about the retinal images and the strain on the accommodation are increased by the proceeding. A similar approximation of print generally takes place among amblyopic subjects. In both instances the retinal images are increased in size, and the area of sentient visual impression proportionably enlarged ; and the advantages attending these results preponderate over the disadvantage of the loss of distinctness of outline, due to the diffusion of the marginal rays.

If the position of the point of intersection is made to alter, the size of the retinal image will be altered also, but this can hardly happen except artificially by placing a convex or concave lens before the eye. If a convex lens be placed before the eye, the point of intersection will be caused to advance, and the retinal image will become enlarged : if a concave lens be similarly placed, the point of intersection will be caused to recede, and the retinal image will be lessened in size.

Field of Vision.—The term "field of vision" signifies the whole of the space, including the objects comprised in it, which is perceptible to sight in one fixed position of the eye, or, in binocular vision, of the two eyes.

Monocular Field of Vision.—When a single eye is directly fixed in a given direction its horizontal limits of visual perception are comprised within an angle of about 123°.

Binocular Field of Vision.—When both eyes are fixed on an object situated at such a distance in front of the observer that the visual axes of the two eyes are practically parallel with one another, the limiting line of visual perception or luminous impression on each side forms an angle of about 90° with the visual axis, so that the field of vision of the two eyes under these conditions has a horizontal limit of about 180°. A certain central portion of the visual field is common to both eyes ; the right and left temporal portions of the field are only proper to the right and left eyes respectively.

Measurement of the Monocular Field of Vision.—Instruments specially constructed for examining and providing the data for mapping out a field of vision are called *perimeters*. In the absence of these special instruments, the extent and shape of the field of vision of an eye may be obtained by causing the patient to look at a given point, and, while the eye is fixed upon it, drawing an outline of the boundary of distinct vision in all directions around it. The most convenient plan is to place the patient with one eye covered, and the other free, at a distance of about two feet in front of a black board placed perpendicularly to the line of sight. On this board, at a level with the eye under examination, a small cross in white chalk is drawn. The patient is desired to fix his eye on this mark. At the same time the surgeon, who must watch that the patient does not look away from the cross, holds a piece of chalk between his fingers of his right hand, and carries it from point to point over the board by slight quick movements of the hand, jotting down the points in various directions where it ceases to be seen. These points are now joined together by lines, and thus an outline of the shape of the field of vision is formed. If the map thus made be copied on paper, it can be retained for comparison with other diagrams to be made in a similar way on future occasions.

If it be important to examine the field of vision with greater precision, separate outlines can be obtained by a similar plan showing where vision sufficiently distinct to count fingers ceases, and more externally where imperfect vision or luminous impression ceases and complete absence of sight begins. Any loss of visual function in particular spots of the retina may also be traced and noted during the examination by moving the chalk slowly and carefully over the field, and directing the patient to mention whenever it disappears from view altogether or is only seen obscurely. Particular irregularities of form, and limitations in extent, of the field of vision will often be rendered manifest by this mode of examination in cases of weak and defective vision depending on disorders of the optic nerve and retina.

When it is not required to make a picture of the field of vision but only to ascertain quickly the extent of the field, or whether there is any break in it in any given direction, the following method will answer the purpose readily and quickly. The surgeon, standing about two feet off, and face to face with the patient, desires him to close one eye, the right, for example, and at the same time closes his own left eye opposite to it. He now desires the patient to look steadily into his right eye, and while the two eyes, the one of the surgeon and the other of the patient, are thus directed to each other, the surgeon moves his forefinger from a central point midway between his own eye and that of the eye under observation, in all directions towards the limits of the field of vision. He is thus able to note the extent of the patient's range of vision, by comparing it with his own range. This ready method has the advantage of being capable of being put into execution anywhere without need of any appliances or previous preparation.

Movements of the Eye.—The external muscles connected with the globe of the eye cause it to revolve round an ideal centre—its centre of rotation. Consequently if the anterior aspect of the eye is caused to move in one direction, the posterior aspect of the eye will be caused to move in the opposite direction. The movements of the eye are commonly described with reference to the movements of the anterior pole of the optic axis or central point of the cornea. When the central point of the cornea accords with the point of intersection of one line drawn transversely between the apices of the two angles of the palpebral aperture, and another line drawn vertically midway between its two extremities, or does so very closely, allowance being made for the slight angle formed by the intersection of the optic axis and visual axis, the eye is said to be directed straight forwards; when the centre of the cornea is above or below the horizontal line just named, the eye is said to be directed upwards or downwards respectively; and if to the inner or outer side of the vertical line just named, it is said to be turned inwards or outwards respectively. It is in accordance with these distinctions of position that when strabismus exists the displacement of the deviated eye is said to be internal or convergent, external or divergent, and upwards or downwards. In normal binocular vision, when the two eyes are looking directly forwards at a distant object, the visual lines are practically parallel with one another, and perpendicular to an imaginary line joining the centres of rotation of the two eyes.

Field of View.—The term "field of view" signifies the space over which objects can be seen clearly by an eye when it moves round its centre of rotation to the extreme limits of which it is capable, the head of the observer at the same time remaining stationary, as in binocular vision, the range of view of the two eyes under like conditions.

Normal Range of Motion of the Eye consistent with Vision.—I find that my own eye can turn through an angle of about 140° horizontally, and of 138° vertically, and perception of objects be retained. On my eye being directed to a point straight before it, it can turn from it 50° towards the nose and nearly 90° degrees outwards in the horizontal plane, or through an angle of 48° from it upwards and 90° downwards. These measurements are not, however, universal; they are subject to variations according to individual circumstances, viz., to personal peculiarities in the shape and amount of projection of the parts near to the eye, as the nose, the margins of the orbit, the eyebrows, and other structures.

Objects on the Visual Field.—The place and space occupied by objects in the field of vision are measured by the visual angles under which they are seen. The *apparent size*, or lineal measure, of an object is estimated by the size of the visual angle alone. To estimate the *true size*, the distance of the object, as well as the size of visual angle, must be known. Conversely, the *true size* of an object being known, the visual angle enables us to form a judgment of the distance at which it is placed from us. The apparent size, or lineal measure, is to be distinguished from the apparent *superficial* size, or measure of surface of an object. The lineal measure, as before mentioned, varies inversely as the distance of the object; the measure of surface varies in proportion to the squares of the lineal measure at different distances.

Brightness of Objects at Different Distances.—The vividness o the light under which objects are seen at different distances does not vary with the distances at which they are respectively placed, excepting so far as those which are more remote may be affected by the thicker stratum of air through which they are seen, provided that all the objects face in the same direction. Supposing the atmosphere to be perfectly clear and transparent, the apparent illumination of two targets, one more remote than the other but facing in the same direction, will be exactly similar. A transverse section of the cone of rays entering the pupil from each illumined point of the farther target, and therefore the total quantity of light emitted by the whole target, will vary inversely as the square of the distance to which the target has been removed, and so also with the apparent area of the target. If one target be placed at double the distance of the other, the area of its image on the retina will be reduced one-fourth of that of the nearer target, but so also will be the amount of light entering the eye from the target, and the effect as regards apparent brightness will necessarily remain the same. The area of the image on the retina is reduced in the same proportion as the quantity of light which forms it.

Motion of Objects in the Field of Vision.—The movement of any visible object *across* the visual field, or the change of its position relatively to the positions of other objects, is, of course, accompanied by a similar movement of its image across the retinal picture. The movement which is thus rendered visible is called its *apparent motion.* If the object move in a direct line towards the centre of the eye, no change occurs in the position of the image of the object, and its movement is not apparent. The extent of apparent motion of an object is measured by its *angular motion;* that is, by the angle formed by two lines drawn from the point of visible departure, and point of visible arrest of motion, of the object, to the point of intersection within the eye. The *real movement* of an object, in respect to direction and extent, is estimated by other means—by its change of apparent size as its distance varies, by its relations to other objects in the visual field as regards position, distance, distinctness, and other indications.

It is not to be forgotten that if the object moving across the field subtend too small a visual angle, or passes with too great rapidity, or is insufficiently illuminated, its movement may not be apparent; either because its image impinges on too minute a portion of the retinal surface to render it perceptible, or because there is not light enough to make an adequate visual impression, or because time enough is not given for the impression to be made. The movement of a gunshot travelling *across* the field may not be apparent for the reasons just named; while, on the other hand, a similar shot or shell moving in a nearly direct line towards the eye may be seen because its image is sufficiently persistent, while, although it has no angular motion, its movement of approach may be inferred from increase of size or the louder sound proceeding from it in proportion to its increased nearness to the observer.

Judging Distance.—An important part of the instruction of recruits at rifle drill practice consists in teaching them to estimate correctly the distances of objects by ocular observation alone, that is, without the aid of range-finders, or other means of measurement. If a bullet on being fired from a rifle travelled in a straight path nearly to the end of its course, there would be no need for soldiers to become skilled in judging the distances of objects, or for adjusting their rifles to those distances, for the bullet would strike any object it might meet in its path within the limits of its range; but since its path, or trajectory, instead of being straight is curvilinear, it is evident that the bullet in its fall can only strike an object of the height of a man within a certain limited space. If the object be outside this space, either in front of or beyond it, it will not be hit. Hence the necessity for a correct knowledge of the distance of any object that may be aimed at, in order to adjust the rifle to it, and so to ensure it being hit by the bullet in its fall.

The power of *judging distance*, as it is called, with approximate accuracy, is therefore essential, for without this knowledge a soldier cannot use his rifle efficiently.

The faculty of judging distance depends upon the capability of properly appreciating the differences in the *visual angles*, or in other words, the differences in the sizes of the retinal images, formed by an object of known size, a man or horse for example, at different distances. The visual angle, and, therefore, the retinal image of an object, lessens as its distance increases. In proportion then as the distance of an object of given size from the eye of an observer is increased so will be the diminution of the apparent size of the object; and conversely, in proportion as the apparent size diminishes, so will be the increase in distance of the object from the eye of the observer.

The acquirement of the art of *judging distances* is effected by causing the men under instruction to note the apparent size and aspect of soldiers placed at certain distances, to observe and familiarise themselves with the appearance of different parts of the figure, limbs, accoutrements, and dress of the men, and to make comparisons between them and the appearances of the same soldiers and objects at various other distances. The appearances of surrounding objects, such as trees, buildings, &c., at different distances, are also impressed on the soldier's mind. The practice is facilitated by observing that certain parts of the men or objects on their persons disappear from view at particular distances; this fact depends, other things being alike, on the visual angles formed by these parts at such distances being too small to permit recognition. In like manner, and from the same cause, the whole object according to its size will disappear from view at some particular distance, even though no other impediments to a clear view of it exist. (See Ch. VI, pages 111 to 115, for further remarks on this subject).

The difficulty of judging accurately the distances of all objects is greatly increased when they are placed far away from the spectator, yet it is under these circumstances that in using the rifle the need for forming a precise judgment of the distance of any object that may be aimed at is greatest. Hence, the experience derived from repeated practice, and accurate observation and comparison of surrounding objects, as well as of objects themselves, together with very perfect qualities of sight, are essential for a man to become a good marksman at objects at long ranges, when the estimate of the distances at which the objects are placed depends on the marksman's own judgment, as it must often do in military operations on active service in the field. The drop of a bullet increases in curvature in proportion to the elevation for distance given to the rifle, and of course the space within which an object of the height of a man would be liable to be struck is lessened in the same proportion. In firing at distances up to 300 yards at a target 6 feet in height, the bullet does not rise anywhere more than 6 feet above the ground, and hence a man of that height would be hit at any point of the bullet's path within this range; but if elevated to suit a distance of 400 yards, the space within which he could be hit by the bullet in the latter part of its course, would be limited to 110 yards; if at 800 yards, the limit of the dangerous space would be lessened to 45 yards; if at 1000, there would only be a space of about 20 yards within which an object 6 feet in height would be liable to be struck. It is obvious that at such long distances, and under such reduced visual angles as objects of the height of an infantry soldier or trooper would subtend at them, the eye must be capable of getting retinal images quite clear of circles of diffusion in order that the objects may be distinguished plainly.

A certain amount of assistance in judging the relative distances of objects, when several are regarded in succession, is derived from the sense of the varying efforts of accommodation, and also from a consciousness of the consentaneous movements of the two eyes in changing their positions for the purpose of so adjusting their visual lines that they may meet together in the same points of the different objects under observation.

It is not to be forgotten that, irrespective of the particular quality and condition of the dioptric media of the eyes of any individual observer, the character of the retinal image of an object and the acuteness of the visual impression produced by it, will be modified very materially by the degree of illumination of the object, the position of the sun in regard to it, the character of the background, particularly its amount of contrast with the object, and the state of the atmosphere between the object and the observer in respect to its transparency and refractive stability.

Aiming.—Before a recruit is permitted to practise firing his rifle either with cartridge or ball, he has to go through a course of instruction in "aiming drill," or the mode of aligning the "sights" of the rifle on the object aimed at; in other words, in so holding his rifle that the parts of it named, and the object to be aimed at, all simultaneously occupy positions in the line of vision. There are two sights attached to the rifle, technically called the *backsight* and the *foresight*; a slide on the former being capable of being raised to various heights, while the foresight is fixed. The recruit is taught to look steadfastly with his right eye along the bottom of a notch in the backsight in the direction of the projecting top of the foresight, which, in turn, is to cover the centre of the mark towards which the eye is directed. The backsight has to be kept perfectly upright, and the slide upon it to be so placed as to adjust the rifle in respect to elevation to the special distance of the object ordered to be aimed at. The recruit is instructed to fix his eye steadfastly on this object, not on the barrel of the rifle or the foresight, keeping his left eye closed, while he brings the top of the foresight in line with the object through the notch of the backsight. If more than the tip of the foresight is brought up into the alignment, a little additional elevation of the rifle is the result. This instruction is carried on for increasing distances until the soldier has become perfect in aiming, for the difficulty of aligning the foresight accurately increases as the distance of the object increases.

Medical officers are occasionally appealed to by the musketry instructors on account of their meeting with difficulties in getting some men to adjust the sights of the rifles so as to bring them into true line with the object, and then to doubts arising in their minds whether the men concerned are not suffering from defective eyesight. It is well, therefore, for medical officers to be prepared with a knowledge of the visual conditions which may facilitate or hinder men from taking a correct aim.

When a Martini-Henry rifle is brought to the front of the right shoulder of a soldier in the standing position the distance of the notch in the slide of the backsight is about 15 inches, and of the "tip" or "fine sight" of the foresight about 39 inches, from the right eye. When an object, such as the bullseye of a target at a distance of several hundred yards, is aligned with these sights of the rifle, it is obvious that an eye, if it tried to do so, could not see the three different objects with equal distinctness at one and the same time. The recruit, therefore, is rightly instructed to fix his eye steadily on the mark he is to aim at—not on the sights or the barrel of his rifle, which, although not directly looked at, can yet easily be brought into the line of vision with the bullseye of the target. As soon as the sights and object are brought together into true line, the recruit is rendered conscious that they are so, by the simple fact that the foresight, projected through the notch of the backsight, intercepts some of the rays of light reflected from the bullseye of the target which would otherwise reach his eye; and he learns that his rifle, if its elevation be duly adapted to the distance, is then in the right direction for a missile discharged from it to strike the target. He does not look at, or recognise with distinctness either of the sights of the rifle; he only sees clearly the bullseye of the target, and at the same time observes its partial obscuration owing to the intervention of the foresight.

Monocular Aim.—The recruit is taught to close the left eye when aiming at an object with his rifle. By so doing he confines his view to the object and a comparatively limited field around it, while he is able to align the sights of the rifle upon the object. It is doubtful whether this plan is advantageous under all circumstances, especially when the object aimed at is not a fixed one at a given distance, as it is at target practice.

Binocular vision gives a more vivid impression of the object from both eyes being simultaneously centred upon it, while it enables the observer to obtain a better notion of its distance and form, as well as of the direction and rate of its motion, when the object is a moving one, such as an enemy running or riding in an open landscape. But a man cannot align the sights of the rifle upon a given distant point when both eyes are open and visually directed towards that point. He can only do so if he has the power, although both eyes are open, of arresting the use, as it were, of the one eye while the other is taking aim; that is, of mentally suppressing note of the image formed on its retina. When one eye only is used, the sights of the rifle, or such parts of them as are not covered by other parts nearer to the eye, and the object aimed at are all in the visual line, and consequently together form an image on the most sensitive part of the retina, the fovea centralis. When both eyes are used, and the object aimed at is a long distance off, the visual lines are nearly parallel, and the distant object is imaged on the fovea centralis of each eye with binocular advantages; but, under these circumstances, the images of such near objects as the sights of the rifle are formed on parts of the retina outside the region of the fovea centralis, and are consequently less distinctly visible than they are when they are in the course of the visual line under monocular vision. For either of the sights of the rifle to be seen distinctly the visual lines must have a very different relative direction; the two eyes must converge on the sight concerned, and the visual lines be inclined toward it at an angle corresponding with the proximity of the object.

These facts may be illustrated by two simple experiments with a rifle.

When a distant object is regarded with a single eye, the other being closed, the rifle and sights aligned upon the object are seen with a certain amount of distinctness; if, without any change of position, the other eye be now opened, and both eyes are directed on the distant object, the distinctness of view of the rifle and its sights, especially of the backsight and parts approaching the stock, is at once lessened. The rifle is no longer in the line of sight; it is outside of it. Or if an object be aimed at from a rest, and the rifle be placed in a straight line midway between the two eyes while they are fixed on the object, the object may be seen distinctly, but the rifle, and of course its sights with it, appears very shadowy, because it does not coincide with either of the visual lines of the two eyes; it is between them. The backsight, if elevated, will probably appear double under such conditions.

If a rifle be not at disposal the same facts may be illustrated simply by the hand alone. If the knuckle of the right hand be applied against the lower border of the right orbit, and the forefinger extended so as to cover a portion of a distant object, while the left eye is closed, the finger and object will be seen together with more or less distinctness, being together in the line of the visual axis; if now the left eye be suddenly opened, the finger will disappear from view, while a more vivid perception of the distant object, and a more extended view of its surroundings, will be obtained. After a short time, if the mind be intently directed to the purpose, the use of the left eye may be suppressed although the eyelids remain open, when the finger and the object to which it is directed will be again seen together with a certain amount of distinctness. This will be more easily accomplished by persons who are in the habit of ignoring the image formed in one eye, as happens with surgeons who are accustomed to use the ophthalmoscope, microscope, and other such optical instruments, or as many sportsmen do who are in the habit of firing with both eyes open. Consideration of the facts just mentioned will explain why musketry instructors find that men who can't shoot with an approach to accuracy at a mark when both eyes are open can shoot fairly with one eye closed, although there is no difference in the two eyes as regards refraction or visual power.

As the central line of the notch of the backsight and the slender ridge or tip of the foresight are very fine objects, and very accurate recognition of them is necessary in ensuring their perfect alignment with a distant object, it seems probable that in taking a precise aim, they are each looked at in rapid succession, in other words, that an alteration of accommodation takes place from one to the other object, but so rapidly that the view of them is practically simultaneous, so that the alternate adaptation of vision to the different distances escapes notice. If such a rapid visual adaptation be essential for ensuring a perfect aim, as seems likely, it is obvious that a person who is either hypermetropic or presbyopic in any considerable degree would experience special difficulties in taking a correct aim with a rifle at a remote object; for he could not see the foresight of the rifle with sufficient definition and alertness. A hypermetropic eye, even at the recruiting age, if the hypermetropia amount to — 2 D, sees a small object, such as the tip of the foresight, so very hazily, that accurate alignment, unless the optical defect is corrected by a suitable lens, is out of the question. Also for a myopic eye, if the myopia be of corresponding amount, or equals + 2 D, alignment is rendered very difficult because, although the tip of the foresight is less obscured than it is with the hypermetropic eye, there is still such reduplication and haziness of the distant object as to make the amount of the foresight brought up into the alignment and the relative positions of the sights of the object all very uncertain. If the ametropic condition be complicated with astigmatism, a certain amount of distortion of form is added to the haziness of view already mentioned, and the difficulties in the way of accurate alignment are increased.

Strengthening the Eye for Shooting at Long Ranges.—It is laid down in the book of Musketry Instruction that "it cannot be too strongly impressed on every man that to shoot well at long ranges he must train and strengthen his eye by looking at small objects at long distances." ("Musketry Instruction," 1884, par. 77, p. 84.) A study of the conditions on which accurate vision of distant objects depends sufficiently shows that if an eye be emmetropic, neither the eye nor the quality of vision for such remote objects admits of increased strength or improvement; if an eye be myopic from natural formation, there is no reason for believing that exercise on distant objects will lessen the degree of myopia or its effects; or, if it be hypermetropic, make up for the deficiency otherwise than by the ordinary exertion of accommodation. But other conditions on which accurate shooting also depends may be developed, and these belong more to the brain than to the eye. Minute features and peculiarities of a given object and its surroundings, which are unnoticed at first view, are rendered familiar and attract critical attention under close and repeated observation, and relations of size and distance of objects become more correctly estimated. It is by these means that painters perceive particular features of a face or landscape, and sailors see and distinguish objects on a distant horizon, although the images of those objects are not pictured with any more precision in their eyes than they are in the eyes of others with the same quality of sight who, however, fail to recognise their presence in the field of view. The artist and sailor learn to observe with more precision, and they acquire by practice the art of distinguishing and rightly interpreting differences, often very slight, in form and colour, or contrasts in light and shade, which are unnoticed by a less observant or less experienced spectator, notwithstanding he may be his equal in strength of eye and acuteness of vision. It is not the strength of the eye which is developed so much as the faculty of observation, and it is to this the attention should be chiefly directed.

The recent introduction of figure targets as objects to be aimed at in the range practice at musketry instruction will probably assist men in acquiring an increased facility of judging distance. The different distances at which the 6-feet figure is fired at along the range must tend to educate the eye and to enable it to estimate rightly any particular distance of the figure through the familiarity which will gradually be obtained with the different appearances presented by it at the various distances it is fired at.

Infinite Rays.—This term, in reference to vision, is employed to express rays of light proceeding from an object and entering the eye in parallel lines, or rather in lines which are so nearly parallel with each other that their divergency is inappreciable; and the expression "infinite distance," or "*infinity*" is used to signify the distance from which such rays come to the eye. The angular measurement of that portion of the cone of rays proceeding from a luminous point which is admitted into an eye is determined by the distance of the point from which the light radiates, and by the diameter of the pupil, or, in other words, the distance apart of the opposite borders of the pupillary aperture by which the passage of the rays is limited. The rays proceeding from luminous points on any object distant from about 6 feet from the spectator up to that of the most distant star, for all practical purposes pass into the eye parallel with each other, and are spoken of as *infinite rays.* The divergency of a pencil of rays from a luminous point at a distance of 6 feet from the eye (supposing the diameter of the pupil to be one-eighth of an inch) would only amount to six minutes of a degree. At a distance of 36 feet the angle of divergency would be only one minute of a degree. Rays from objects nearer than 6 feet are sometimes spoken of as *finite rays.* The divergency of finite rays increases in proportion to their proximity to the eye.

Lenses.—Lenses of primary form are solid transparent media, such as glass or rock crystal, bounded by a polished spherical surface on one or both sides, and having the property of changing the course of rays of light falling on one of their surfaces in a direction parallel with the principal axis, so as to cause them either to *converge* to a given point—the principal focus; or to *diverge* as if they proceeded from the principal focus.

Cylindrical lenses will be described separately.

Convex and Concave Lenses.—The lenses which are chiefly used for optical and ophthalmoscopic purposes are centric convex and concave lenses; the former having two convex surfaces which are portions of equal spheres, double convex lenses, and the latter having two concave surfaces which are also portions of equal spheres, double concave lenses. They are sometimes designated centric biconvex or equi-convex, and bi-concave or equi-concave lenses. The *convex* or *converging* lenses are thicker in the middle than at their edges; the *concave*, or *diverging* lenses are thinner in the middle than at their edges. A double convex lens may be regarded as composed of two prisms with their bases joined at the centre; and a double concave lens of two prisms having their bases outwards, and their edges meeting at the centre. Rays of light whose passage has been limited to the lateral parts of a convex or concave lens, are acted upon as they would have been if they had passed through prisms with their bases in similar directions. In either kind of lens, a line joining the centres of curvature of the two surfaces is the *principal axis* of the lens. The more convex the lens, the greater its converging power; the more concave the lens, the greater its diverging power.

The *principal focus* of a convex lens will be at the point to which rays falling on one of its surfaces parallel with its principal axis, and passing through its substance, are caused to converge and meet beyond its other surface. The distance of this focus is measured from the *optical centre* of the lens. The measurement has hitherto been usually made in inches and parts of inches; but on the Continent is now commonly made in metres or parts of a metre, and this is gradually becoming the system in British optical measurements. The optical centre of a double convex or double concave lens, with surfaces of equal sphericity, is situated at the point where the principal axis of the lens is intersected by a diameter of the lens. Any straight line, other than the principal axis, which passes through the centre of a lens is designated a secondary axis. In common speech, for the sake of brevity, the principal focus of a convex lens is spoken of as *the focus* of the lens: and the distance of this focus is used to particularize the lens. Thus taking, *e.g.*, a lens whose principal focus is at 10 inches from its centre, it is often designated as a convex lens whose focus is at 10 inches, or a lens of 10-inch focus, or, still more briefly, as a 10-inch lens; or, according to the metrical system, is a lens of four *dioptrics*, having its principal focus at a distance of one-fourth of a metre, or a No. 4 lens. Convex lenses have what are called *real* foci.

If the rays falling on a double convex lens are divergent, and issue from a distance beyond that of its principal focus, they will be brought to a focus farther off than its principal focus; if they diverge from a point at the distance of the principal focus, they will be refracted as parallel rays; if they are convergent, they will be rendered more convergent and will be brought to a focus nearer to the lens than its principal focus.

Rays falling on a double concave lens parallel with its principal axis, are caused to diverge after passing through it to the same extent as they would diverge if they were proceeding from a point at the same distance from its centre as its principal focus is. In other words, the emergent rays of such a lens, if produced backwards, would meet in the principal focus of the lens on the same side as the incident rays. If the rays falling on the double concave lens are divergent instead of parallel rays, they will be rendered proportionably more divergent, just as if they came from a point nearer to the lens than its principal focus. If they are convergent, and they converge in a direction toward any point between the lens and its principal focus, the refracted rays will be convergent also; if they converge to a point at the distance of the principal focus, they will be refracted as parallel rays; if they converge towards some point beyond the distance of the principal focus, the refracted rays will be proportionably divergent, just as if they were proceeding from some point further off from the lens than the distance of its principal focus. Concave lenses have what are called *virtual* foci.

Regarding the eye as a combination of lenses having together a certain converging power, when a convex lens is placed closely before it, the converging action of the eye on rays entering it from objects in front is necessarily added to; when a concave lens is similarly placed before the eye, its converging action on these rays is lessened. The convex lens, therefore, is rightly designated in this respect a + lens; the concave lens a – lens. It is convenient too in calculating the focal distances or powers of lenses required to correct abnormal conditions of the refractive media of the eye, to apply the sign + to converging lenses, and – to diverging lenses. Thus, a convex lens of 10-inch focus is designated a + 10-inch lens, or, in metrical numeration, a + 4D (4 dioptric) lens; while a concave lens of 10-inch focus is noted as a – 10-inch lens, or – 4 D lens.

When a convex lens is placed before the eye, it causes an advance of the nodal point of the eye, and thus increases the size of the retinal image; when a concave lens is similarly placed, it causes the nodal point to recede, and so lessens the size of the retinal image.

Numeration of Lenses.—Lenses are usually numbered according to one or other of two systems; one known as the duodecimal or *inch system*, the other as the *metric system*. Although the metric system is certainly the more advantageous, and is doubtless destined to supersede all others for optical practice, it is as yet only used to a limited extent by surgeons and opticians in this country, while the inch system still continues the one employed in commerce. Until the metric system is generally adopted, the principles of both systems should be understood, and surgeons, whose duties require them to engage in optical work, should be familiar with the means of readily changing the measurements from one system into those of the other.

According to the inch system or older method of numeration, lenses are numbered according to the position of their principal focus. A lens whose principal focus is one inch from its centre, is taken as the standard of unity. Starting from this high point, a series of lenses, usually 25 (25 + and 25 — lenses), descend in succession with lessened refracting power, and, consequently, with the position of the principal focus proportionally increased in distance.

In the metrical system, which was first proposed at Paris in 1867 but only brought into practical use in 1876, the lenses are not numbered according to the position of the principal focus, but according to their refractive power. A lens of such refracting power that its principal focus is at a distance of 1 metre, or 100 centimetres, is taken as the standard of unity. This in ordinary language is designated a *dioptric*. Starting from this low point, a series of lenses ascends with successively increased refracting power, and, consequently, with the position of the principal focus proportionally shortened in distance. Thirty lenses constitute the usual series in this system, that is, 30 + and 30 — lenses.

Power of a Lens in relation to the Position of its Principal Focus.—By the inch system of measurement, the strongest lens being taken as No. 1, the numbers attached to all other lenses represent fractional *parts*, as regards refracting power, of the standard of unity. The *power* of each lens is in an inverse ratio to the distance of its principal focus. Inverting the number expressing the principal focal distance of a lens, therefore, gives a ready means of expressing its power. Thus, taking a lens with power to cause parallel rays to converge to a focus at a distance of 1 inch from its centre as the standard of unity, another lens by which similar rays are brought to a focus at 2 inches from its centre, has manifestly only half the dioptric power of the former; another, whose focus is at 3 inches, has only one-third of the converging power of the first; at 10 inches, one-tenth; and so on through the whole series. In the first instance the focus is 1 inch, and the power is expressed as 1; in the second, the focus is 2 inches (or $\frac{2}{1}$), and the power is $\frac{1}{2}$; in the third and fourth cases, the foci being 3 and 10 inches respectively (or $\frac{3}{1}$ and $\frac{10}{1}$) the powers are $\frac{1}{3}$ and $\frac{1}{10}$; and similarly through all the series.

By the metrical system of measurement, as a lens of very feeble power is taken as No. 1, the numbers of other lenses represent *multiples* of the standard of unity, and the *distance of the principal focus* is in an inverse ratio to the *power* of the lens. Inverting the power, therefore, gives the position of the focus. One dioptric, or a lens of one metre focus, being the standard of unity, a lens which has the power of two dioptrics, or a No. 2 lens, has its focus at a distance of half a metre, or 50 cm.; another, which has the power of four dioptrics, or a No. 4 lens, has its focus at one-fourth of a metre, or 25 cm.; of ten dioptrics, No. 10 lens, one-tenth of a metre, or 10 cm., and so through the whole series of lenses.

Comparison of the Two Systems of Numeration of Lenses.—The difference in the practical working of the two systems is very great. Two important changes have been effected by the introduction of the metric system. The potential intervals between the successive numbers of lenses have been simplified, and errors from the different lengths of inches in different countries, and consequent variations in lenses nominally of the same power, have been avoided.

In the inch system of numeration, as regards the difference in power between lenses of successive numbers, no two intervals are alike throughout the series. The difference in power between a 2-inch lens and a 3-inch lens, or lenses with powers equal to one-third and one-half of the standard of unity, is equal to a 6-inch lens, or lens of one-sixth power; between a 3-inch lens and a 4-inch lens is a 12-inch lens, or lens of one-twelfth power; between a 4-inch and 5-inch lens is a 20-inch lens; and is equally irregular throughout.

In the metrical system, the value of the interval between the adjoining whole numbers is always alike. The difference in power is uniformly that of one dioptric. A No. 2 lens has twice the power of the No. 1 lens; a No. 3 lens is one dioptric stronger than the No. 2 lens; a No. 4 lens is equally one dioptric stronger than the No. 3 lens. A No. 10 lens has the power of 10 dioptrics, and the same regularity prevails throughout. In working on this system it is always known that on taking a next higher whole number among the convex lenses, the converging power is increased by the strength of one dioptric, and in taking the next lower number, it is decreased by the strength of one dioptric; or, on dealing similarly with concave lenses, that the diverging quality is increased or decreased to the same amount. The relative strength to one another of all the lenses in the metrical series is thus at once made known by their numbers.

When the inch system is employed, the difference in value of the inches proper to different countries has to be taken into account. The English, French, Austrian, and Prussian inches all differ in length, and, though unimportant when dealing with weak lenses, these differences if ignored are liable to lead to important errors in optical practice when dealing with lenses of high powers. The Paris inch is ·02707 of a metre, the English inch ·02540; and thus the Paris inch exceeds the English inch by one-sixteenth, or, in other words, 16 Paris inches are equivalent to 17 English inches. The metre is of course the same in all places, and thus the difficulties arising from the different values of inches in different countries are avoided.

Another advantage of the metrical system of numeration of lenses is stated to be that the necessity no longer exists for using vulgar fractions, which is unavoidable in working with the inch system. If the most powerful lens of a series be taken as the standard of unity, all the other weaker lenses must necessarily be fractional parts; if the weakest lens of a series be taken as the standard, all the other stronger lenses will be multiples of it. To those who are not ready arithmeticians, calculations of multiples are easier than calculations of fractions. This, however, only applies to whole numbers. If parts of whole numbers are introduced into the series, fractions, either decimal or vulgar, must be used in calculations concerning them. In certain parts of the metrical system of lenses the intervals are fractional, and in using these parts decimal fractions are employed.

The Series of Metrical Lenses.—Although the number of metrical lenses in use, as before stated, is 30, the highest in the series is 20D, having a focal length of one-twentieth of a metre, or 2 inches. Under the inch system, although a 1-inch lens is taken as the standard of unity, the highest number employed in practice is also a 2-inch lens. In the metrical arrangement, the separation of a whole dioptric would have made too great a difference in the lenses of low power at the commencement of the scale. On this account the lenses have been added to by quarters up to 3 dioptrics, and by half dioptrics from 3 up to 6 dioptrics. From 6 up to 20 dioptrics, the difference in the focal distances is too slight to be broken. A table is given which shows the composition of the whole series of lenses.

To convert Lenses numbered on the Inch System into their Equivalents in the Metric System.—If the number of the lens be in Paris inches, invert it, and multiply by 36; if in English inches, multiply its inverted number by 40; the result will be the corresponding dioptric number. Thus a 12″ lens, Paris measurement, whose power is $\frac{1}{12}$″ multiplied by 36, is equivalent to a metrical lens of 3D; or a 10″ lens, whose power is $\frac{1}{10}$″, English measurement, multiplied by 40, is equivalent to a lens of 4D.

Or, more simply, if the lens be numbered in Paris inches, divide 36 by the number; if English inches, divide 40 by the number. Thus a 12″ lens in the former case is $= \frac{36}{12}$ or 3D; in the latter is $= \frac{40}{10}$ or 4D; a 14″ lens, Paris inches $= \frac{36}{14} = 2·57$D; a 16″ lens, English inches $= \frac{40}{16} = 2·50$D.

To convert Lenses numbered on the Metric System into their Equivalents in the Inch System.—If required to be in Paris inches, divide the metric number by 36; if in English inches, divide the number by 40. Thus a 4D lens has for its equivalent in the inch system, Paris inches, $\frac{4}{36}$" or $\frac{1}{9}$", or a 9" lens; in English inches, $\frac{4}{40}$", or $\frac{1}{10}$", or a 10" lens.

To find the Measure of the Principal Focus of Lenses numbered on the Metric System.—If the distance be required in centimetres, divide 100 by the dioptric number; if in Paris inches, divide 36 by this number; if in British inches, divide 40 by the number. Thus, taking for example a 4D lens, its focal distance is $\frac{100}{4}$, or 25 cm.; or $\frac{36}{4}$, or 9 Paris inches; or $\frac{40}{4}$, or 10 British inches. Or again, taking a 0·50D lens, its focal distance is $\frac{100}{\cdot 50}$, or 200 cm.; or $.\frac{36}{50}$, or 72 Paris inches; or $.\frac{40}{50}$, or 80 English inches.

Table of Metrical Lenses and their Relative Values in English Inches.—The French metre being equivalent to 39·3707 English inches, as before shown, for practical purposes this may be regarded as 40 English inches. The calculations in the following table have been made on that basis.

Dioptric number.	Focal length in metres.	Approximate focal length in English inches.
0·25	4	160
0·50	2	80
0·75	1·333	53
1	1	40
1·25	0·800	32
1·50	0·666	26·66
1·75	0·571	23
2	0·500	20
2·25	0·444	18
2·50	0·400	16
2·75	0·363	14·54
3	0·333	13·33
3·50	0·286	11·50
4	0·250	10
4·50	0·222	9
5	0·200	8
5·50	0·182	7·33
6	0·166	6·66
7	0·143	6
8	0·125	5
9	0·111	4·50
10	0·100	4
11	0·091	3·75
12	0·083	3·33
13	0·077	3
14	0·071	2·85
15	0·067	2·66
16	0·062	2·50
18	0·055	2·25
20	0·050	2

Cylindrical Lenses.—A cylindrical lens is one which has the curvature of a cylinder instead of that of a sphere; it is, in fact, a segment of a cylinder. The opposite sides of a cylindrical lens are parallel with each other in the direction of the axis of the cylinder of which it is a segment, while there is more or less curvature between them in all other directions. The curvature is greatest in the direction perpendicular to that of the axis of the cylinder. The foci of cylindrical lenses may be either positive or negative. There are several kinds of cylindrical lenses.

Simple Cylindrical Lenses.—Ordinary cylindrical lenses are cylindrical on one side only and flat on the other. They are known as *plano-convex* or *plano-concave* cylindrical lenses. But, like spherical lenses, they may be bi-convex or bi-concave, or convex-concave or concavo-convex lenses. In these, which have both surfaces cylindrical, the axes must be parallel. The plano-convex and plano-concave cylindrical lenses are the lenses chiefly employed for trying and correcting simple forms of astigmatism.

Bi-cylindrical Lenses.—These are lenses with both surfaces cylindrical, but with the axes of the cylinders perpendicular to each other.

Action of Cylindrical Lenses upon Light.—Rays of light falling upon a cylindrical lens are acted upon differently according as they fall upon the lens in a plane coincident with the axis of the cylinder of which it is a segment, or in a cross direction. Rays incident in the plane of the axis of the cylinder pass through it as through glass with opposite parallel surfaces, or as if it were a piece of plate glass. Rays incident in a plane at right angles to the axis are acted upon according to the amount of convexity or concavity of the glass in this direction. The more convex or the more concave the surface, the more convergent or more divergent the rays will be rendered after their passage through the cylinder in this direction, just as happens with spherical lenses. The essential difference between a spherical lens and a cylindrical lens is that in the spherical lens all the rays which fall on it are altered in direction by their passage through it, while in the cylindrical lens similar rays pass through it unaltered in one direction, but altered in the opposite direction. A spherical lens brings the image of a source of light to a point, while a cylindrical lens brings the image to a line instead of a point.

Spherico-cylindrical Lenses.—These are compound lenses, of which one surface has a spherical, the other a cylindrical curvature. They are chiefly used in the correction of compound and mixed forms of astigmatism.

Trial Case of Lenses.—A case of lenses of various descriptions and powers employed for purposes of optical investigation. A complete trial case usually includes full sets of the convex, concave, and cylindrical lenses just described, each bearing a distinguishing mark of its quality and power, together with a series of prisms, coloured glasses, stenopœic diaphragms, opaque discs, and two pairs of lens-holders or trial frames.

Trial Frames or Lens-holders.—Two kinds of frames are required for holding lenses to serve as spectacles, and are generally supplied with each trial case. One with a single groove is arranged for holding a pair of spherical lenses; the other with a double groove for holding cylindrical lenses in addition to the spherical lenses. The posterior grooves are intended to hold the spherical lenses; the anterior, the cylindrical lenses. The metal rim of each of the hemispheres within which the cylindrical lens is placed is divided into degrees, plainly marked on the surface; so that any required inclination may easily be given to the axis of the cylindrical lens held by it.

Ready Tests of Convex, Concave, and Simple Cylindrical Spectacle Lenses.—It is frequently necessary to ascertain rapidly the nature of a lens. This can be readily done in the following manner:—On holding the lens a few inches in front of some printed type and looking through it at the print while the lens is moved in a plane parallel with the plane of the print, if the print is enlarged and appears to move in an opposite direction to the movement of the lens, the lens is convex; if the print is diminished in size and appears to move in the same direction as the lens, the lens is concave; and if in either case the same occur equally in whatever direction the lens is moved, the lens is centric. If the respective movements just described only occur in one direction, the print appearing to remain stationary when the lens is moved in the opposite direction, the lens respectively is a simple + or — cylindrical lens.

Similar indications will be obtained if the lens be moved an inch or so in front of the eye, and an object at a distance of some feet off be looked at through it. If the lens be a centric convex lens, the object will appear in all directions to move the opposite way to the movement of the lens; if it be a concave lens, it will appear to move in the same direction. If it be a simple convex cylindrical lens, the dimensions of the object will be elongated in one direction, and in this direction will appear to move opposite to the movement of the lens; while it will seem to be shortened, but show no movement, when the lens is moved in a contrary direction. This latter will be the line of direction of the axis of the lens. If it be a simple concave cylindrical lens, the dimensions of the object looked at through it will be lessened in one direction, and in this direction will appear to move in concert with the movement of the lens; while it will seem to be elongated, and show no movement, when the lens is moved in the contrary direction. The last-named will be the line of direction of the axis of the lens.

To ascertain the Power of a Convex, Concave, or Cylindrical Lens.—This may be readily done in the case of a centric convex lens, even without a trial case of lenses, by ascertaining the distance of its principal focus. The rays of light from a window frame 15 or 20 feet away, or, as is often done in opticians' shops, from the large letters on a shop front on the opposite side of a street, are allowed to pass through the lens and are received on a piece of white card or other suitable screen. At one distance only can a clearly defined and sharp picture occur of the object from which the rays have come, and the measure of this distance from the lens gives the distance of its principal focus, and therefore of the power, of the lens under examination.

This cannot of course be done in the case of a diverging lens. When the power of a centric concave lens is sought, it must be ascertained by neutralising it by a convex lens of known power. This is quickly managed with a trial case of lenses at hand. A convex lens is taken from the case, placed in contact with the concave lens, and an object, such as the bar of a window frame, looked at through the two lenses combined while they are moved in front of the eye. If the bar appear to move in the opposite direction to that of the lenses, the convex lens is stronger than the concave lens; if the bar appear to move in the same direction, the convex lens is less strong than the concave lens; when the bar, seen through the two lenses, shows no movement on the lenses being moved, the concave lens is exactly neutralised, and the power of the convex lens being known, that of the concave lens is also known.

In the same way the power of a convex lens may be quickly ascertained, if a trial case of lenses is at hand, by finding the concave lens which exactly neutralises it.

In the case of a convex cylindrical lens, the principal focus, and therefore its power, may be ascertained by measuring the distance from the lens at which a point of light, as a candle placed at the distance of 10 or 15 feet, is brought to a sharply defined line of light on a screen. The power of a concave cylindrical lens must be found by neutralising it by convex cylindrical lenses of known power; and, indeed, both forms of cylindrical lenses can have their powers most quickly ascertained by neutralisation by opposite kinds of cylindrical lenses taken from a trial case of lenses, in the same way as concave and convex spherical lenses. The axes of the two opposite kinds of cylindrical lenses must be so placed as to coincide exactly in direction.

Army Optical and Ophthalmoscopic Case.—In the combined optical and ophthalmoscopic case which used to be supplied to officers of the Army Medical Department, in addition to the convex and concave lenses belonging to the ophthalmoscope, there was a pair of spectacles fitted with 10-inch convex or + 4 D lenses. Parallel rays falling on such lenses are caused to converge to foci at a distance of 10 inches from their respective centres; while divergent rays proceeding from points at 10 inches distance from their centres are refracted by them as parallel rays.

Formerly spectacles with concave – 6″ lenses were also supplied in this optical case; but the supply was discontinued because it was found that their employment could be dispensed with without inconvenience.

Images formed by Convex and Concave Lenses.—Images are representations of objects formed by concourse of the pencils of rays emanating from all the points of the objects which they represent. All the points of a perfect image are the conjugate foci of the rays which have proceeded from corresponding points of the object.

When an image is formed in the focus of a lens, and can be received on a screen, as at the focus of a convex lens for example, it is called *real* or *positive;* when it is not formed by the actual union of rays in a focus, but only appears to be so, and cannot be received on a screen, it is called a *virtual* image.

An image is *erect* when the object and image lie on the same side of the centre of the lens; is *inverted* when the object and image lie on opposite sides of the centre. The retinal image of any object in front of the eye is an example of a *real* and *inverted* image.

The diameters of the object and its image are directly as their distances from the centre of the lens; as they separate from this point, the farther off either is, the greater its proportionate size.

When an object is placed between a *convex* lens and its principal focus, an eye on the other side of the lens sees a *virtual* image of the object, erect, magnified, on the *same side* but at a greater distance from the lens than the object. It is on this principle that microscopes are formed. If the object be farther off than the principal focus, but its distance be less than twice the focal length of the lens, the image is *real*, *inverted*, *magnified*, and on the *opposite side* of the lens to the object; if the distance of the object be greater than twice the focal length of the lens, the image is *real, inverted*, *diminished*, and on the *opposite side* to the object.

When an object is placed in front of a *concave* lens, an eye on the other side of the lens sees an image of the object which is *virtual*, *erect*, *diminished*, on the *same side* and nearer to the lens than the object. The image is diminished when the distance between the lens and the object is increased; but when the distance of the object is a large multiple of the focal length of the lens, further increase of its distance does not appreciably alter the distance of the image, or, consequently, its size.

Composition of Optical Lenses.—Lenses for spectacles are either made of crown glass or quartz, and it is useful for surgeons to have some knowledge of their respective qualities and occasional defects. Lenses made of quartz are described by the opticians who sell spectacles as "pebbles," or "rock crystal," and are usually recommended by them as being clearer and cooler to the eyes than glass. The clearness of view through pebbles depends on the quality and manipulation of the quartz, and can very rarely, if ever, be equal to that of the best crown glass; any superiority in coolness is very problematical. The only real advantage of "pebbles" is their greater hardness, so that their surfaces are not scratched and dulled so easily as those of glass lenses. Unless the quartz is unusually pure and transparent, is scientifically cut and shaped as regards refraction, it is a decidedly inferior material to good crown glass for optical purposes; and it is doubtful whether pebbles do not remain more trying to the eyes, even when proper attention is given to the requisite qualities just named, than spectacles of the best crown glass such as is specially manufactured for spectacle lenses. Quartz has the quality of double refraction, and although it may not be perceived by the eyes in thin lenses of low powers, the images of objects on the retina are less perfect in distinctness in consequence, especially if the quartz is not well cut, and a certain amount of exercise of accommodation takes place in trying to render them sharp and single. The only way to cut rock crystal so as to avoid double refraction, is to cut it exactly perpendicular to the axis of the crystal, so that the axis of the lens which is formed from it may coincide, or be parallel with the axis of the original crystal. This operation is difficult except in comparatively rare specimens of perfectly crystallised quartz, requires special skill, and renders the lenses more costly.

It is sometimes desirable to establish whether a pebble lens is properly cut or not. This can readily be done by looking through the lens placed in a tourmaline forceps, which may be procured at the establishments of all good opticians. The blades of the forceps consist of two thin plates of tourmaline, one of which can be revolved in front of the other, and they admit of a lens being placed between them. On turning the movable tourmaline plate, when it arrives in a certain position the transmitted light becomes polarised, and is as it were extinguished. If a quartz lens is now placed between the tourmaline plates, the light is depolarised, and the field becomes luminous; if the lens were a glass lens, the field would remain dark. This serves to distinguish between a glass and a pebble lens. On further examination of the quartz lens, if it has been cut perpendicular to the axis of the crystal, its centre will be seen occupied by a series of concentric coloured rings; if no such rings appear, it has been cut in a contrary direction. If the rings appear toward the edge of the lens, or are elliptical in form, it is defective, for it has been cut obliquely in respect to the axis of the crystal.

Glass lenses for spectacles should be made of pure, colourless, and perfectly homogeneous crown glass. They should approach as nearly as possible in limpid transparency to that of the dioptric media of a young and perfect human eye. Inferior lenses are made of a bad quality of crown glass, having more or less of a greenish tint, not unfrequently containing microscopic air globules, specks, or striæ, owing to an imperfect mixture of the vitrifiable ingredients which enter into the composition of the glass. The lenses are thus rendered unequal in their refractive power, and in consequence are proportionably trying and injurious to the eyes that use them.

Spectacles.—When lenses are applied in the form of spectacles for the purpose of relieving visual defects, several points of optical importance require attention. Glasses of the proper description and power may be ordered by a surgeon, but however good in quality the lenses may be, unless they are rightly disposed by the spectacle maker, their purpose may not only not be attained, but the eyes concerned may be much inconvenienced by them. Spectacles often require the inspection of the surgeon who has ordered them, to ascertain whether his directions have been carried out.

Spectacles should be so arranged that the visual axes pass through the centres of the lenses. The frames containing the lenses must therefore be accurately measured and fitted, neither too narrow nor too wide. If the visual axes do not pass through the centres of the lenses, the line of sight of each eye will be either to the outer or to the inner side of the centre of the corresponding lens. If the lenses used be convex, and the line of sight pass through the outer part of each lens, as in too narrow spectacles, the rays arriving at each eye from the object looked at, are acted upon as if they had passed through a prism with its base turned inwards; if the line of sight of each eye pass through the inner part of a convex lens, as will happen when the lenses in the spectacles are placed too far apart, the rays of light from the object looked at are changed in direction, as they would be in passing through a prism with its base directed outwards. The position of the two eyes must change in order to meet the altered directions of the rays falling on the macula lutea. In the former case the eyes will have to converge less, in the latter case more; and where the spectacles are used for near objects, as in presbyopia for reading, the increased demand made on the action of the muscles of convergence, and the disparity caused between the exercise of convergence and that of the accommodation for the distance at which the print is placed, will entail a sense of strain and uneasiness (asthenopia) about the eyes. When concave spectacles are worn, and are not properly centred, the effects will be the reverse of those just named for convex glasses. The necessity for the visual axis passing through the centre of each lens, involves a difference in position of the lens according to the purpose for which the spectacles are worn. If they are used for correcting distant vision, as in myopia and hypermetropia, the two lenses must be parallel with one another; if for correcting vision of near objects, they should be inclined at such an angle toward each other as to allow the visual lines to pass through their centres to the visual distance of the objects looked at through them. So with bi-focal spectacles, in which the upper half of the spectacle is used for distant objects and the lower lens for objects near at hand, the upper lens sections should be placed parallel with the vertical planes of the two eyes when looking forward, and the lower lens sections connected with them at such an angle, about 75°, as will preserve the same correspondence in direction when the eyes are turned downwards towards objects close at hand, as in reading, the centres at the same time being moved slightly inwards, to allow for the convergence of the two eyes. When one side of a spectacle is allowed to drop to a lower level than the opposite side, an occurrence which may not unfrequently be noticed, the visual axis of one or other eye no longer accords with the centre of the lens before it, and the discord leads to visual disturbance. A horizontal line joining the two centres of the lenses of a pair of spectacles ought to be exactly parallel with a similar line joining the centres of the pupils of the two eyes. A want of congruence in this respect is a frequent source of error when folding glasses are used.

Distances of Spectacles from the Eyes.—When spectacles are worn to correct refractive defects of the eyes, they should be so adjusted that the lenses are placed as near as possible to the anterior focus of each eye, *i.e.*, about half an inch (13 mm.) in front of the cornea. When they are worn to correct failure of accommodation (presbyopia), the positions of the lenses are less important; if they are removed an inch or so further from the eye than its anterior focus, the only effect will be to modify slightly the apparent size of the objects looked at, and to alter the position of the near point of distinct vision. This is met by suitably adjusting the distance at which the objects looked at are placed.

Eyeglasses.—The use of a single eyeglass by any one who has the use of both eyes is not to be recommended, excepting in rare cases, when its purpose is to adjust the refractive power of the eye before which it is placed, so as to make it agree with that of the eye which is left free. If the effect of the glass is simply to assist the vision of the eye to which it is applied, while that of the other eye is left unattended to, the action of an eyeglass becomes more or less deleterious. The two eyes should always, as far as practicable, be exerted in concert; if the retinal image in one be habitually suppressed, the unused eye will in time become amblyopic. Eyeglasses are not allowed to be used at target practice at the School of Musketry, though spectacles may be worn.

Spectacle Frames.—The frames should be well fitted to the form of the face, should not press on the temples, but should only rest on the bridge of the nose and the top of the ears, and, whatever the metal of which they are made, should be sufficiently firm to maintain the right positions of the lenses. When they are used for vision at near objects, or for work in which the face is required to be bent forward, it is advantageous for the extremities of their sides to be curved so as to hook behind the ears, and be thus prevented from shifting or dropping off.

Pantoscopic Spectacles.—A name given by opticians to spectacles in which a portion of the upper margin of each lens is cut away, so that they are nearly flat at the top and oval below. They enable the spectator to see over the lenses when he is not looking at near objects. The lenses, and the parts of the frames holding them, are set at an angle with the sides of the frames, so that the upper borders of the lenses are tilted to a certain extent forwards. They are suitable for emmetropic persons who have become presbyopic. Some convex lenses are made perfectly flat above with the usual oval below; while other concave lenses have this shape reversed, and are made oval above and flat below for myopic persons. As spectacles of these last two kinds are occasionally used by artists, they are usually sold under the name of "sketching spectacles."

Equi-convex and Equi-concave Spherical Lenses in Spectacles.—Rays which pass through the secondary axes of a spherical lens, although impinging obliquely, are not much altered in direction on leaving the lens, because the opposite surfaces near the centre are nearly parallel; but as rays approach the circumference of the lens, they become more and more oblique relatively to the curvature of the lens, are more strongly converged on emergence, and consequently have a tendency to intersect at points nearer to the lens than its principal focus. This deviation is known as *aberration of sphericity*. It gives rise to a certain amount of imperfection in the use of bi-convex and bi-concave spherical lenses as spectacles when the eyes are so turned as to look obliquely through them. As the rays most free from deviation are those which most perfectly coincide with the principal axis of the lens, it follows that, as before mentioned, vision through a spectacle is best when the eye looks direct through its centre ; and it is for the purpose of maintaining vision in this direction that persons wearing spectacles, even when perfectly fitted, or using a glass, are in the habit of turning the head altogether towards an object in cases where persons without spectacles would merely turn their eyes.

Periscopic Glasses.—Lenses concave on one side, convex on the other ; Meniscus lenses. They are positive or minus lenses, according as their convexity or concavity is respectively in excess. They have been designed to overcome the effects of the spherical aberration just referred to of equi-convex and equi-concave spectacles. They in some measure enable the wearer to see more obliquely and hence to have a wider field of view ; to look round with less inconvenience when the eye only is turned, and hence their name.

Orthoscopic Glasses.—Spectacles, so called by Dr. Schefler, who has written very fully on their advantages, consisting of eccentric portions of spherical convex or concave lenses, so that they may be regarded as a combination of lenses and prisms. They are arranged on the principle that the deviation of the rays of light caused by the prism may be in proportion to the changes in the visual distance caused by the lens.

Their intended purpose is to correct disproportions between the exertion of accommodation and the convergence of the visual lines, which occasionally exist when ordinary convex and concave centric lenses are used in assisting vision of objects at certain distances near to the eyes. If perfectly arranged, the action of the prisms would cause the visual lines to converge and meet at precisely the same distance as the principal focus of the lens, and, by their being balanced, there would be no need of undue exertion on the part of either the muscles of convergence or accommodation. The results of the use of orthoscopic glasses are not satisfactory ; they are inconveniently heavy, and they produce a certain amount of distortion of the objects looked at, disadvantages which more than counterbalance their advantages.

Duplex Focal, Bi-focal, or Franklin Glasses.—Spectacles with the upper half adapted for looking at distant objects ; the lower half for near objects. They are elsewhere referred to. The lower segment is united with the upper at an angle so that the visual axis, in the different positions required for seeing distant and near objects, falls on the surface of each segment at a right angle.

Thus the upper segment may be made to correct H. ; the lower H. combined with Pr. ; or the upper to correct M., as regards distant vision, the lower to correct M. for some relatively near distance, or Pr., as in the glasses first used by the philosopher Franklin, after whom they are named.

Tinted Spectacles.—Plain glasses, or convex and concave lenses, may be tinted in various shades of blue colour, or may be simply darkened (neutral or smoke-tinted glasses), with a view to lessen the effects of glare, as of tropical light, or sunlight reflected from snow or water, or to prevent the irritation caused by light in photophobia from any cause. For this latter purpose blue-tinted glasses are the best, as they neutralise the most irritating rays of the spectrum, the orange rays. Opticians supply eight degrees of saturation of blue-tinted glasses. A set of specimens obtained from a leading manufacturing optician in London were designated by a series of numbers, the saturation being least in No. 1 and gradually increasing to No. 8. They also supply eight shades of neutral or smoke-tinted glasses, respectively distinguished by the letters A to H, the saturation being least in A and gradually increasing to H.

Eye Protectors.—Spectacles so called because they are chiefly employed to protect the eyes against dust, grit, or in certain trades against particles of metal and other substances which would injure the eyes if they reached their surfaces. They consist ordinarily of spoon-shaped but plain glass, having such forward convexity as readily to cast aside particles on striking them, and equally to protect the eyes from the force of a strong wind when meeting it in front. When blue-tinted, and they are correct in form, they are very useful for protecting weak eyes against the irritating influence of orange-coloured light, and also against the glare of the sun, as in India and other tropical countries. They allow air to pass freely over the eyes upwards and downwards, and thus are far better than glasses so shaped as to fit close to the orbit, for these heat, relax, and sometimes inflame the eyes by impeding the normal evaporation of their secretions, and by preventing the access of any air to them. They are also better than double spectacles with glass sides, which are objectionable not only on account of heating the eyes but also on account of their weight.

The eye protectors sold in some shops require careful examination, as they are not unfrequently defective in form, so that they do not act simply as a cover and shade to the eyes, but operate as convex lenses, and fatigue vision by causing a certain amount of distortion of objects. They can be easily tested in the same way as has been already described with regard to convex and concave lenses. Inferior glasses are also not unfrequently coloured unevenly in the grain of the glass, and sometimes contain specks and other imperfections, which are less noticeable than they would be in unstained glass, owing to the fact of the glass being tinted. Such defects are always more or less detrimental and disturbing to vision.

Goggles.—These are also contrivances for protecting the eyes against dust, glare, and other sources of irritation. They are formed of various materials, wire gauze, or a combination of wire gauze and glass, and may be set in spectacle frames or only fitted to the orbits, and held in place by ribbons that may be tied behind the head. The goggles supplied to the troops engaged in the recent military operations in Egypt consist of two oval flat pieces of blue-tinted glass, set in front of two boat-shaped fine wire-gauze sides. The glasses and the gauze wire were kept in shape by narrow steel frames or borders, and the whole was so fashioned that the edges fitted closely to the bony margins of the two orbits. The eyes were thus completely enclosed within the goggles. Each pair of goggles were connected on their inner aspects by a piece of cord admitting of a certain play, so that the goggles might adapt themselves to eyes at different distances apart; and at their outer edges were connected by a piece of elastic cord sufficiently long to permit it being passed over the ears and behind the head, and to hold them in position when they were worn. When not required for use one goggle could be placed within the other goggle and the two put together in an oval japanned tin box, 2½ inches long by 1¾ inches across, and 1 inch deep, for security. Portability, lightness, and comparative cheapness were thus secured, while they answered the purpose of warding off the grosser particles of sand and diminishing glare.

Prismatic Glasses.—Spectacles fitted with prisms, or with prisms in combination with convex and concave lenses, are occasionally used for various optical purposes; such as to correct slight declinations of the visual lines, whether upwards, outwards, or inwards, and thus to prevent visual confusion from double images; or to relieve asthenopia depending on undue strain of the M. recti interni, as when persons with high degrees of myopia read a work at near distances at which there is little or no parallel exertion of accommodation with that of the convergence. Their action will vary according to the position given to the prism. (See Prisms.)

Stenopœic Hole.—A very small circular opening in the centre of an opaque metallic diaphragm. The effect of the stenopœic hole, when the eye looks through it, is to exclude the marginal rays of the cone of light, proceeding from each illuminated point of an object, which would otherwise pass through the pupil, and thus to lessen the area of the circle of diffusion on the retina in the case of any eye that is not emmetropic. At the same time that the marginal rays are excluded, a certain portion of the light emanating from an object is necessarily also excluded, so that the luminous impression on the retina is proportionably diminished. Objects looked at through a stenopœic hole appear darker, and both the range of vision and the advantages of ocular movements are curtailed by it. The stenopœic hole is often of use in determining whether deficiency in acuteness of vision is due to ametropia or to some other ocular defect. It is very important for optical purposes that the margin of a stenopœic opening should be perfectly clean and even.

Stenopœic Slit.—A narrow slit in an opaque metal diaphragm. The effect of the stenopœic slit, when placed before the eye, is to limit the entrance and passage of rays of light to one meridian of the eye. It may be conveniently employed in the diagnosis of astigmatism.

Stenopœic Holder.—An appliance provided with a stenopœic slit, so arranged as to be capable of being lessened or increased in width, and adapted for holding concave or convex spherical lenses. The appliance is provided with a suitable handle. It is chiefly employed in the diagnostic examination and in the correction of astigmatism.

Stenopœic Glasses.—Opaque glasses with very narrow openings, either in the form of a circle or of a slit, for limiting the transmission of rays of light to the eye. They are used to improve vision, when only a particular portion of the dioptric media is clear, by preventing the disturbance due to light being diffused through partial obscurations of the cornea or of other of the dioptric media; in irregular astigmatism, to restrict the passage of light to a particular portion of the cornea; and also when it is desired to lessen the amount of light entering the eyes, as in tropical countries in cases in which the iris is permanently dilated from any cause, or in which the iris or a large portion of it has been removed by iridectomy.

Strabometer or Strabismometer.—An instrument for measuring the linear extent of deviation of the centre of the cornea of an eye, which is displaced literally from the position it would occupy in normal binocular vision on the two eyes looking directly forward at a distant object, as happens in convergent and divergent strabismus. It consists of a small ivory plate, fitted with a handle, and made suitable in shape for being applied to the lower lid of an eye. At the curved margin of the plate a scale of marks and figures is engraved, indicating distances in millimetres, or parts of inches, on each side of a central mark which is intended to be placed in line with what would be the normal situation of the centre of the cornea. As soon as the instrument is adjusted, the distance of the displaced corneal centre from the line indicating this normal position can be at once read off from the instrument.

Prisms.—Prisms of different powers are used in certain parts of ophthalmic practice, especially in the investigation of *strabismus* and *diplopia*. Prisms for optical purposes essentially consist of a solid piece of crown glass contained between five plane surfaces, of which three—two *sides* and a *base*—are rectangular, and two—the *ends*—triangular, these latter being at right angles with the base of the prism, and therefore parallel with each other. The line of junction of the two inclined surfaces, or sides, is the edge of the prism; each triangular end represents a *principal section* of the prism. In order to adapt them for use in front of the eye, however, the angles are sometimes rounded off, and a shape thus given to them which is nearly circular. When rays of light are made to fall upon one of the sides of a prism, and to pass through it, they are refracted towards its base, and the degree of their deflection on issuing from the other side of the prism varies according to the size of the angle enclosed between the sides through which the refracted light has passed, or, in other words, according to the *angle of refraction* of the prism. As a consequence of these qualities, when an object is looked at through a prism, its apparent position is changed;

it seems to shift its direction towards the edge of the prism, and the distance to which it appears to be shifted from its normal position increases with the increase in the refracting angle of the prism. Taking advantage of these facts, the rays from a given object may be made to impinge upon any part of either retina, by the use of prisms of different degrees of strength; and by these means the presence or absence of binocular vision may be determined in doubtful cases, diplopia may be counteracted, and single vision restored, or the relative strength of the several motor muscles of the eyes may be tested.

When a pair of prisms of equal refracting angles are placed before the two eyes with their bases outwards, and an object situated at a limited distance is looked at, it appears at first to each eye to be displaced in a direction towards the edge of the prism or inwards, and the strain on the muscles of convergence of the two eyes, the recti interni, in order to preserve single vision is increased; when the prisms are placed with the bases inwards the object appears to each eye to be displaced outwards in the direction of the edges of the prisms, and not only is the extra strain on the recti interni muscles then taken off, but the need for the normal action of these muscles may be lessened.

The strength of the convergent power of the eyes may be measured by causing the two eyes to look in the manner just described at an object situated in a plane midway between them, through two prisms with their bases directed outwards. The object which appears to be displaced in the direction of the edges of the two prisms respectively, or across the median line, if the prisms be of sufficient strength, will be seen double, and, if the power of the prisms is greater than that of the internal recti muscles to fuse the double images into a single one, the two images will remain at a certain distance apart. The highest refracting angle in the prisms which can be overcome by the muscular efforts, as shown by the fusion of the two images into a single image, affords the measure of the extent to which the converging faculty can be exerted.

In like manner, if the bases of the prisms be held inwards, the limit in diverging power of the external recti muscles may be measured.

The prisms supplied in the cases of eye lenses and prisms in ordinary use have angles of refraction varying from 3° to 24°.

Abbreviations.—The following abbreviations are occasionally employed in this manual: Em. for Emmetropia; M. Myopia; Hm., manifest Hypermetropia; Hl., latent Hypermetropia; H., absolute Hypermetropia; Ast., Astigmatism; C., Convergence; Cyl., Cylindrical; V. acuteness of vision; Pr., Presbyopia; P., proximate or nearest point of distinct vision; R., remote, or most distant, point of distinct vision; Sn., Snellen's types; D., dioptric; 1 m., one metre; 1 cm., one centimetre; 1 mm., one millimetre.

Symbols.—The following symbols are also found useful as abbreviations for expression of measurements:—1', one foot; 1", one inch; 1''', one line; ∞, infinite distance, or infinity.

CHAPTER II.

Vision according to varieties of Focal Adjustment.—Chief Varieties.—EMMETROPIA.—Definition.—Optical Conditions.—Farthest Point of Distinct Vision.—Diagnosis.—MYOPIA.—Definition.—Farthest Point of Distinct Vision.—Nearest Point.—Optical Conditions.—Causes.—Symptoms.—Commencing Myopia.—Association of M. with Strabismus.—Diagnosis.—Expression of Degree of M.—Determination of Degree of M.—Correction of M.—Exaggeration of M. from Spasm.—Over-correction of M.—Extension of Reading Distance in High Degrees of M.—Test in Military Practice for High Degree of M.—Influence of M. in Military Service.—HYPERMETROPIA.—Definition.—Optical Conditions.—Farthest Point of Distinct Vision.—Nearest Point.—Causes.—Symptoms.—Association of H. with Strabismus.—Manifest and Latent H.—Subdivisions of H.—Diagnosis.—Expression of Degree of H.—Determination of Degree of H.—Example.—Explanation.—Correction of H.—Influence of H. in Military Service.—ASTIGMATISM.—Definition.—Optical Conditions.—Causes.—Symptoms.—Retinal Images in As.—Amount of As.—Measure of Amount of As.—Kinds of As.—Diagnosis.—Varieties of Regular As.—Examples.—Determination of Principal Meridians in As.—Their Refractive Conditions.—Correction of Regular As.—Examples.—Irregular As.—Influence of As. in Military Service.

Chief Varieties of Focal Adjustment.—Measure of focal distance being the chief feature of those conditions of vision which depend upon the optical adjustment of the eye in a passive state of rest or the state in which there is no active exertion of accommodation, all varieties in this respect may be classed under three heads or natural divisions. They are expressed by the following terms:—1. EMMETROPIA, focus in correct measure, the refractive power of the eye being normal: 2. HYPO-METROPIA, under measure, or Brachymetropia, focus short in measure, the refractive power of the eye being in excess: 3. HYPER-METROPIA, focus beyond measure, the refractive power of the eye being deficient in degree. But, as regards No. 2, Hypo-metropia and Brachy-metropia, the old classical term—MYOPIA, derived from the habit of short-sighted persons partially closing or nipping together their eyelids, is so familiarly known, and is so convenient for avoiding mistakes from similarity in sound between the Greek derivatives signifying under and over, that its use has been universally continued.

AMETROPIA, not in measure, is a term which simply signifies that the condition of emmetropia does not exist: it therefore comprehends the condition of myopia as well as that of hyper-metropia.

ASTIGMATISM is a variety of disordered focal adjustment of a compound nature, the chief features of which, when considered separately, are, however, subjected to one or other of the three leading divisions above named.

The terms ISOMETROPIA, with its adjective form *isometropic*, are sometimes used to express briefly that both eyes of an individual are equal in refractive quality and power; ANISOMETROPIA, and *anisometropic*, that, although similar in refractive quality, they differ in their degrees of that quality; ANTIMETROPIA, that they are dissimilar in quality, as when one eye is emmetropic but the other ametropic, or that their refractive qualities are both defective and at the same time opposite in kind, as when one eye is myopic and the other hyper-metropic.

The varieties of focal adjustment before named, as already mentioned, refer to the refractive quality of the eye when it is in a state of rest or repose; but the focal adjustment of all eyes under normal conditions may be more or less changed by the exercise of a special function, named ACCOMMODATION. This function is described elsewhere (see p. 80).

EMMETROPIA.

Definition.—Normal sightedness, in respect of the refractive power of the eye in a state of repose, that is, when it is not exerting any of its accommodatory power.

Optical Conditions.—The dioptric media of the eye are so adjusted, that, by means of their combined refractive qualities, rays of light emanating from distant objects, that is, objects at a distance of 15 or 20 feet and upwards, and falling upon the eye practically as parallel rays are brought accurately to a focus upon the anterior surface of the sentient layer of the retina. In other words, the retina is so placed as regards measure of distance, that it is precisely in the plane of the principal focus of the dioptric media of the eye; the two distances, that of the retina and that of the principal dioptric focus, are in perfect harmony.

Farthest Point of Distinct Vision.—Infinite distance; or the distance of the farthest visible objects, the fixed stars for example. However great the distance of an object may be, so long as the other conditions necessary for vision, viz., sufficient size and illumination, are preserved, a perfectly defined retinal image of it will be formed by the emmetropic eye.

Diagnosis of Emmetropia may be established subjectively, (1) by types, (2) by spectacles, and (3) objectively by the ophthalmoscope.

1. *By Types.*—The emmetropic eye, other conditions being normal, can read any of Snellen's types at the indicated distances with facility.

2. *By Spectacles.*—Vision of distant objects is not improved either by a convex or concave lens as a hyper-metropic or myopic eye respectively would be, but, on the contrary, is deteriorated in proportion to the increase in power of the lens applied to the eye. Printed letters of small type can be read at a distance of 10 inches from a convex 10-inch, or + 4 D lens, placed in front of the eye at the distance of the anterior focus of the eye, about half an inch from the cornea, for the rays of light coming from the print are thus caused to fall on the eye as parallel rays. The farthest point of distinct vision of the emmetropic eye with a convex 10-inch, or + 4 D lens, before it is at 10 inches.

Occasionally, as age becomes advanced, the subject of vision which has been regarded as emmetropic finds that he derives some advantage, as regards distant vision, from the use of convex glasses of moderate degrees of power. This is a change which Professor Donders designated "acquired hyper-metropia," and in his great work on *Anomalies of Refraction* he has given a diagram showing from various observations the course of this change. According to this diagram the change begins at middle life, and at 80 years of age the acquired H. amounts to a deficiency of refractive power equivalent to 1·5 D, or a lens having a focus of 26¼ inches. It is questionable whether in such instances the so-called acquired condition of H. is really due to senile changes, or whether the eyes under observation have not always been hyper-metropic, although the H. has not been detected, owing to its being supplemented by a certain amount of accommodation. Practically, however, whatever the explanation may be, whenever the condition exists, the fact that vision for distant objects is improved by convex lenses takes the eyes under observation out of the category of emmetropia and puts them in that of hyper-metropia.

3. *By Ophthalmoscopic Observation.*—(See page 71).

MYOPIA.

Definition.— Syn.: Hypo-metropia. Short-sightedness. Near-sightedness. The measure of distance of the principal focus of the dioptric media of the eye is under the measure of the principal axis of the eye, and the focus, therefore, does not reach the plane of the retina. The refracting power of the eye, when it is free from all exercise of accommodation, is in excess by comparison with that of an emmetropic eye; so that parallel rays from remote objects are brought to a focus in front of the retina. Only divergent rays are focussed upon the retina; vision is, therefore, acute as regards objects within limited distances, while it is indistinct as regards distant objects.

Farthest Point of Distinct Vision.—A fixed limited distance in front of the eye, the measure of which varies according to variations in the degree of myopia.

Nearest Point of Distinct Vision.—This also varies in distance with the degree of myopia, but is always nearer to the eye than it is in a person of emmetropic vision at a corresponding age.

Optical Conditions.—To produce a myopic condition of vision, either the antero-posterior axis of the globe of the eye must be prolonged beyond the distances of the principal focus of the refracting media, and this is the general cause in simple myopia; or the refracting qualities of the dioptric media must be increased out of proportion to the length of the eyeball, irrespective of exercise of accommodation. In practice it is most convenient to regard the myopic state as depending on an excess of refractive power in the media of the eye, and to take no note of the increased length of the antero-posterior axis of the eyeball.

Causes.—Hereditary conformation of the eye, myopia, or a predisposition to it, being frequently transmitted by parents, and seen to prevail in many members of the same family.

Morbid changes of which distension, attenuation, and protrusion posteriorly of the sclerotic coat, together usually with an atrophic condition of the choroid coat, form the most conspicuous features. This may either be general, the posterior hemisphere of the eye being elongated in all directions; or, as frequently happens, it is local, the eye being more elongated in the direction of the antero-posterior axis than in other directions. (Staphyloma posticum.)

Conditions in which the convexity of the cornea is unduly increased.

Long-continued convergence of the eyes and ocular over-exertion at near objects, under which circumstances a certain amount of elongation of the globe is produced, going on if the origin of the mischief is not stopped to staphyloma posticum. Under similar conditions the capsule of the lens may lose some of its subjectiveness to change of form, or, from being so constantly accommodated for a very near point, the accommodatory apparatus may cease to be able to relax itself sufficiently to allow parallel rays to be brought to a focus upon the retina. In this last case the parts concerned in accommodation would be primarily in fault, but acquired myopia would become one of the results.

Certain neurotics, as the extract of the Calabar bean, by exciting contraction of the ciliary muscle and constrictor pupillæ, temporarily change an emmetropic into the condition of a myopic eye.

Symptoms.—In uncomplicated myopia near objects up to a limited point are seen quite clearly. Hence the common name of the affection—near-sightedness. More remote objects are misty, enveloped in a haze, and consequently only indistinctly visible. Distant objects, when highly illuminated or brightly coloured, often appear solid toward their central parts, but attended by a shadowy apparition, or spectral reduplication, of their outlines. The reason that objects near to the eye are naturally seen by a myopic person with precision is that the pencils of rays proceeding from all the illuminated points of these objects impinge on the eye more divergently than they do from distant objects, so that the increase in divergency being rendered proportionate to the over-measure in the convergent quality of the eye relatively to the length of its visual axis, the rays are brought to a focus upon the retina, and proper images are formed there. At the distant limit of distinct vision, the over-refractive quality of the myopic eye is just balanced by the divergency of the rays proceeding from the object looked at at that limit; within that distance, as the rays from objects become more divergent, the accommodatory function is called into play to supplement the refractive quality in order that the eye may still get clearly-defined images on the retina. The reason why an object more distant appears "blurred," or surrounded by a halo, is that after the rays proceeding from it have been brought to a focus short of the retina, they cross each other, proceed divergently, and become spread out upon the retina. An image of the object is then formed, but as the pencils of rays proceeding from the object, instead of being focussed to corresponding points on the retina, are spread out in successive circles, the image is necessarily confused and indistinct. The rays which proceed to form the image consist of a number of sections of diverging cones, and these sections overlap each other in its formation. The circular outline of the image is determined by the form of the pupil through which the rays originally passed into the eye. The diffusion is greatest toward the circumference of the image, because the rays of the conical pencil become more divergent in proportion as they approach its peripheral limits. These scattered rays, for sake of brevity, are called "Circles of Diffusion." The farther an object is removed from the eye the greater is the diffusion on the retina of the rays proceeding from it, for each pencil of rays from the object is brought to a focus at a greater distance from the retina, and the cone of rays proceeding from this focus has, in consequence, a longer axis and a base of proportionably longer diameter where it is intercepted by the retina, than it would have if the ocular focus from which it started were nearer to the retina. The habit which myopic persons have of partially closing their eyelids, and thus narrowing the interpalpebral fissure, when looking intently at a distant object, arises from an instinctive endeavour to prevent some of the peripheral rays of light reaching the eye, and so lessening the circles of diffusion upon the retina.*

Counterfeit or False Myopia.—It is necessary to be on guard against counterfeit M., or a condition which may pass for M., but is really only a semblance of it due to irritation and spasmodic action of the parts concerned in the exercise of accommodation. Prolonged work at small objects, as in etching, long-continued reading small and defective print, and other similar near work, will sometimes induce an imitation of a considerable degree of M., particularly in eyes that are weak from any cause, although no myopia may really be present. A person may exhibit the condition referred to, and may even have a hyper-metropic formation of the eye. The question of the real refractive quality of an eye under such circumstances can only be solved after the power of accommodation has been paralysed by atropia.

Association of Myopia with Strabismus.—Myopia is not unfrequently found to be associated with strabismus. The squint is occasionally, but rarely, convergent, in cases where the internal recti muscles have become disproportionately developed from constant use owing to the approximation of objects for distinct vision, and so do not admit of being relaxed in proportion to the external muscles. It is much more frequently divergent. This prevalence of divergent squint with high degrees of myopia is usually thus explained. As the myopic condition leads the patient to bring small objects near to the face to be seen clearly, strong convergence of the visual axes is also necessary in order to ensure binocular vision; and thus a strain is thrown upon the internal recti muscles, which they are unable to maintain beyond a limited period of time. Moreover, when the degree of M. is so high that the distant point of distinct vision is only a few inches off in front of the eyes, no accommodatory exertion is required as there would be at a similar distance in the case of an emmetropic person. However, at so near a distance Ac. is exercised instinctively in association with the convergence of the visual lines, and the result is that the refractive state of the eye is added to, and the distant point of distinct vision brought still nearer. The M. is, as it were, for the time increased in degree. A greater strain is thrown upon the muscles of convergence, and the desire is naturally created to relieve this strain, and at the same time to get clearer images of objects farther off than the short myopic distant point. Should the length of the antero-posterior axis of the eye increase, increased myopia will be associated with it; and the difficulties of the internal recti muscles in effecting the necessary movements of the eyeballs, and maintaining convergence, will be still further augmented. Under these several circumstances the ocular adductors get so over-fatigued, that they cease to act in true concert, and confused, or double vision, is liable to result. When this happens, one eye, probably the stronger and more acute, will remain directed to the object in view, while the other eye will deviate a little outwards; a less central, and, therefore, less sensitive portion, of the retina will be brought in line with the object, and thus the production of a mental impression of its image will be avoided with more ease. Or the eye not in use may deviate still further outwards, and receive only the rays coming from distant objects, when, from the myopic state of the organ, very diffuse and easily disregarded images only will result, and so again visual confusion be prevented, and, at the same time, the aching and uneasiness connected with the stretching of the posterior tunics of the globe under excessive convergence will be averted. Under both these conditions vision will be practically monocular, not binocular. The strabismus may be only temporary in its nature, occurring when near objects are fixedly regarded, or it may be rendered permanent by continued repetition of the circumstances just explained, and continue also when distant objects are looked at.

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* I was once informed by some myopic candidates for commissions in the army that they had been advised by trainers to apply Calabar gelatines to the eyes shortly before appearing for physical examination. This would produce contraction of the pupils, and so lessen the diameters of the circles of diffusion, and consequently render the retinal images of distant objects less indistinct. For the time the influence lasted distant vision would in this respect be improved. On the other hand, the use of eserine to produce a condition simulating that of myopia is said to have been not unfrequently resorted to by conscripts on the Continent, for the purpose of avoiding military service: and on this account, in the military regulations of some countries, it is ordered that the ocular examination of conscripts in special cases shall only take place after the accommodation has been paralysed by the employment of atropine. A simulated, or exaggerated, myopic condition artificially produced by the use of eserine would thus be counteracted.

Diagnosis of Myopia.—This may be established subjectively (1) by external signs, (2) by types, (3) by spectacles, (4) by correction, and (5) objectively by the ophthalmoscope.

1. *External Signs.*—The myopic eye usually presents some peculiar characters indicative of its condition. It is prominent, or even appears to protrude; the pupil is usually contracted, and the constant nipping together of the lids produces a noticeable appearance of the parts immediately surrounding the organ. The existence of

divergent strabismus, whether observable only when the eyes are directed to very close objects, or constant, as already explained, may be a further diagnostic sign of myopia.

2. *By Types.*—The myopic eye, if no other defect exist and the myopia be moderate, not above $\frac{1}{24}$, or 1·50 D, will be able to read No. 1 and also No. 2 of Snellen's types at the proper distances, but will not be able to read the larger types at the distances indicated by the figures placed above them. If the degree of myopia be higher than $\frac{1}{12}$ or 3 D, then No. 1 of S. will not be read at quite the distance of 1 foot, and the farthest distance at which the types can be distinctly read will indicate the probable degree of the myopia.

3. *By the Spectacles.*—All convex glasses make vision of distant objects worse; concave glasses, even of very low power, improve vision of distant objects. When the + 10″, or + 4 D spectacles are worn, as before described, one eye being covered, and small type is placed before the uncovered eye at a distance of 10 inches from the lens, it is found that the type cannot be read, but on bringing the type nearer to the lens it becomes legible. The farthest point of distinct vision of the myopic eye with the + 10″ or + 4 D lens before it is, therefore, short of 10 inches. In examining the refractive conditions of eyes with spectacles, the patient should stand with his back to the light, which should so fall on the print as to illuminate it thoroughly. The print should be advanced gradually towards the lens, a rigid inch measure being held at the same time horizontally by the side, and the distance of the first point at which the print becomes clearly defined should be carefully noted. In shading the eye not under examination, the lids should not be closed by pressure of the fingers, but the eye should be simply covered by the hand. If the eye be pressed upon some minutes must elapse before it will recover a suitable condition for optical examination.

4. *By the Ophthalmoscope.*—(See page 71.)

5. *By Correction.*—When the true degree of uncomplicated myopia is ascertained, the proper concave lens for that degree will *completely* correct the abnormal condition.

Expression of the Degree of Myopia.—The degree of myopia may be either expressed by the power of the concave lens whose principal focus is situated at the same distance as the remote point of distinct vision of the myopic eye under observation, or by the power of the convex lens which represents the amount of the excess of refracting power of the eye relatively to emmetropia. The latter mode of expression is the more convenient in practice. Myopia = 2 D or $\frac{1}{20}$ then signifies that the excess of refracting power in the eye equals the power of a + 2 D, or + $\frac{1}{20}$″ lens, and that this excess will be neutralised or corrected by a − 2 D, or − $\frac{1}{20}$″ lens. The distant point of distinct vision of the eye with mycpia = 2 D will be at the same distance as that of the principal focus of the − 2 D lens, viz., at 20 inches' distance.

Determination of the Degree of Myopia.—When the existence of myopia is established, its degree may be determined by simply finding the distance of the remote point of distinct vision of the eye under observation, or, in other words, the farthest point at which small objects can be seen with perfect definition, and beyond which they begin to appear blurred. The distance of the remote point of distinct vision agrees with that of the principal focus of the lens which represents the degree of myopia. But for reasons explained elsewhere it is more convenient in military practice to determine it by means of the + 4 D or + 10″ spectacles. The distant point of distinct vision is accurately ascertained after the + 4 D or + 10″ lens has been placed before the eye at the usual distance of spectacles, viz., half an inch in front of the cornea. Inverting the distance so found, and deducting from it so inverted the power of the lens added to the eye, viz., $\frac{1}{10}''$, the difference gives the degree of myopia.

Exaggeration of Myopia from Spasm.—In most cases of seemingly very high degrees of M., it is prudent to try carefully whether the M. is as high as it appears to be. Counterfeit M., a condition in which no true M. exists, has been already referred to. From causes similar to those which induce counterfeit M., the real condition of M. may become exaggerated in its apparent degree. It will be found in occasional cases that the measure of distance of the remote point of distinct vision is shortened by the spasmodic exercise of a certain amount of Ac., so that the M. is caused to appear higher in degree than it really is. Some myopes read with the print nearer to the eyes than their M. renders necessary. It may be owing to faulty posture, to a habit of reading in a bad light, of reading badly printed books in small type, or to other causes. But under the condition named, an unnecessary amount of Ac. is exerted, and this accommodatory exertion is liable to become so habitual that it cannot be easily relaxed whenever the eyes are similarly employed. The employment of atropine will suffice for the detection of the exaggeration. It prevents the exercise of the accommodation, and by thus removing the added refractive power, will show in any such case of exaggeration, that the M. is not so high as the tests without atropinization made it appear to be. If, in such a case, the apparent, but exaggerated, amount of M. were fully corrected, the true amount of M. would be over-corrected; and constant exercise of Ac. would be required to neutralise this excess of correction even for vision at the farthest distance. The correcting glass, owing to its power being too high, would render the eye in question practically hypermetropic.

Example 1.—Suppose the distant point of distinct vision of the myopic eye with the + 4 D or + 10″ lens before it, is found to be 6″, then M. $= \frac{1}{6} - \frac{1}{10} = \frac{1}{15}$.

Explanation.—Let $x =$ the refracting power of the eye under examination; let $a =$ the refracting power of an emmetropic eye; $\frac{1}{10} =$ the power of the lens to which the eye has been subjected; and $\frac{1}{6}$ equal the power of the lens which would give the ascertained distant point of 6″ if the eye were emmetropic. The excess of refracting power in the example given is therefore obviously equivalent to the difference between a $\frac{1}{6}$th and a $\frac{1}{10}$th lens. This excess can only be in the eye itself, and its refracting power must evidently be reduced to a corresponding degree to bring it to a par with an emmetropic eye.

Therefore $x - (\frac{1}{6}\text{th} - \frac{1}{10}\text{th}) = a$; or $x - \frac{1}{15}\text{th} = a$; or $x - a + \frac{1}{15}$. M., the excess of refracting power over that of an emmetropic eye, is $= \frac{1}{15}$.[*]

Example 2.—If the calculation be made by the metric system, the distance of the remote point must be converted into dioptrics, and the dioptric power of the lens added to the eye, viz., + 4 D, must be subtracted from it. The difference gives the degree of myopia.

Thus, in applying it to the measured distance given in Ex. 1, viz., 6 inches, which is equal to $6\frac{2}{3}$ D; M. $= 6\frac{2}{3}$ D − 4 D $= 2\frac{2}{3}$ D, or, in other words, M. is equal to a lens of 2·67 D, the principal focus of which is at 15 inches.

To find the correcting lens.—The excess of converging power having been determined, it is corrected by a lens of corresponding diverging power. In the example given a − 2·67 D, or a $- \frac{1}{15}''$, or a 15″ concave lens, will be the correcting lens, because this will neutralize the + 2·67 D or $+ \frac{1}{15}$ in excess.

The distant point of distinct vision of the eye in this example when no lens is placed before it will be 15 inches off; or, in other words, the rays of nearest approach to parallel rays which the uncorrected eye is able to focus with accuracy are the rays with that degree of divergency which they have when they start from a point placed at a distance of 15 inches from the eye. A − 2·67 D or $- \frac{1}{15}''$ lens held in front of the eye causes parallel rays from distant objects to have the same degree of divergency as the rays reflected from an object at 15 inches' distance from the eye. The eye is thus rendered competent to form distinct retinal images of objects at infinite distances just as much as it was able to do of the nearer objects at 15″ without the lens.

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[*] *Reasons for adopting the Method described in the Text.*—The use of the constant + 4 D or + 10″ lens for examination of ocular states of refraction is adopted in preference to other methods for military purposes, because it is equally applicable to the determination of Emmetropia, Myopia, and Hypermetropia, and of the degrees in which the two latter conditions exist; because medical officers cannot usually avail themselves of regular series of lenses for conducting such investigations; because the mode of observation can be easily and quickly learned; the observations can be conducted within a moderate range of distance, such as can be obtained in any ordinary room; and further, since the trials are usually made on persons who have no knowledge of the effects of lenses, because efforts at deception, if attempted to be practised, are more readily defeated. Other methods of carrying out the investigation are only briefly referred to in the text, as the main object is to render this manual as concise and simple as possible.

Occasional cases will occur, when atropine has not been employed, in which the true degree of myopia may not be exactly found by the use of the + 10″ lens, because the person under trial has not been able altogether to relax his accommodation when fixing his sight on an object within 10 inches distance; but such instances are very rare when the trial is thoroughly conducted. It is also to be taken into account that the action of the convex lens will cause the retinal images of the printed letters to vary within certain limits in size according to the distances at which the letters may be placed in front of the lens, but practically such variations as occur do not influence the results to any appreciable extent. This is proved by the fact that in cases of uncomplicated myopia and hypermetropia the degree of myopia thus found is shown to be the true one by the corresponding concave lens correcting the vision for distant objects, while the degree of manifest hypermetropia, when atropine has not been used, ascertained by the same means, is equally corrected by the corresponding convex lens.

Mem.—In defining the degree of M. with precision, a slight correction has frequently to be made for the distance at which the trial lens is placed from the eye; and when both eyes together have lenses placed before them, another correction often becomes necessary in practice to compensate for the gain in refraction due to the amount of accommodation in activity which is associated with the convergence of the optic axes when both eyes are employed in regarding an object. Rather weaker glasses are consequently required under the circumstances named than those which the ascertained distant points indicate.

Over-correction of M.—If the use of the lenses which have been ordered for correcting the M. be found to be all that is desired as regards distant vision, but is attended with discomfort and aching when the eyes are employed in work at a moderate distance from the eye, leading to the inference that the Ac. is not effective for work at the distance indicated as would be the case if the eye were emmetropic, it should be ascertained if the M. has not been over-corrected by the lenses supplied, and the eyes brought into a condition of H., as described in the previous paragraph. The eyes should be again tested after they have been subjected to the influence of atropine. If there be no over-correction, but the concave lenses ordered are found to be only equivalent to the excess of refraction, or, in other words, to the degree of M. which they have been calculated to neutralize, it becomes evident that the Ac. from some cause or other is alone at fault, and cannot be exerted to the extent necessary for obtaining clear vision of near objects when lenses fully correcting the M. are placed before the eyes. It is best under such circumstances to prescribe two sets of glasses—one set for fully correcting the M., but only to be employed for distant vision, a second set for use at a relatively near distance. The distance for which the second set should be calculated may vary according to the nature and position of the work to be done with their aid—for such work as reading, for seeing notes of music, or for some mechanical occupation. But under no circumstances should the glasses be calculated for a distance very close to the eyes, or with their use all the discomfort and difficulties attending undue convergence and strain of Ac. will still have to be encountered. A reading distance of at least 1 foot from the eyes should be provided for. This is especially necessary when the degree of myopia is so great as to place the distant point of distinct vision very near to the eyes. It is important to remove this point further off and so prevent the fatigue and nerve irritation entailed by accommodatory strain and excessive convergence. The calculation may be made according to the duodecimal system by lessening the dispersive power of the lens required for full correction and for bringing parallel rays to a focus on the retina to the extent of the power of the lens representing the Ac. that must be exerted to give distinct vision at the distance to which the lens is to be adapted. Thus if a lens of $-\frac{1}{10}$th power, or — 10″ lens, is required to bring parallel rays to a focus on the retina, a $(-\frac{1}{10}+\frac{1}{15})$ lens, or a $-\frac{1}{30}$ in. lens, or — 30 in. lens, will bring the rays diverging from a distance of 15 inches to a focus in the retina. The strong — 10 in. lens is required to correct vision for infinite distance; the weaker — 30 in. lens will be employed for correcting vision at 15 inches' distance.

By the metrical system, in the same case, a concave lens of 4 dioptrics will correct vision for parallel rays, a lens of — 4 + 2·75 D (2·75 dioptrics being nearly the equivalent of 15 inches), or a lens of − 1·25 dioptrics, or of 32-inch focal length, will correct vision for a distance of 15 inches.

Extension of Reading Distance in High Degrees of Myopia.—In like manner in a case where the M. is very high in degree, as $\frac{1}{4}$ for instance, when it would be important to remove the reading or working point of distinct vision from a distance so near to the eye as 4 inches to some distance farther off, the same proceeding may be followed as in the last example given.

Supposing it be desired to remove it to a distance of 12 inches. Then $(-\frac{1}{4}+\frac{1}{12}) = -\frac{1}{6}$, and a concave lens of 6 in. focus would enable the $\frac{1}{4}$ myopic eye to see objects distinctly at a distance of 12 inches. Or by the metrical system, the M. being = 10 D, and the distant point of distinct vision of the eye 4 inches, − 10 D would correct the eye for distant vision, and (− 10 D + 3·25 D), or − 6·75 D would remove the distant point of distinct vision a small fraction beyond a distance of 12 inches from the eye.

Tests in Military Practice for High Degrees of Myopia.—Before concluding the remarks on myopia it may be well to refer to the plan of establishing the presence of high degrees of myopia by means of concave lenses. It has already been mentioned that formerly the army optical and ophthalmoscopic case included spectacles fitted with − 6″ lenses. They were originally introduced into this case for the ready detection of degrees of M. = $\frac{1}{12}$ and upwards. They had been used in the Austrian Army at the suggestion of Stellwag von Carion for determining, on high degrees of myopia being urged by conscripts as a plea for exemption from military service, whether such high degrees did really exist, or otherwise; the degree of M. being deduced from the *near* point at which small print could be read when the − 6″ lenses were worn. The rule laid down was that if a man, when wearing − 6″ spectacles could read small print (No. 2 Jäger) within 6″ distance from the eye, he was obviously so myopic as to be unfit for military service, for he would be myopic $\frac{1}{12}$ or upwards.

A myopic eye of $\frac{1}{12}$″ (about + 3·50 D) is converted into the condition of a hypermetropic eye of $\frac{1}{12}$″ (− 3·50 D) by − 6″ (− 7 D) lenses being placed before it. At the age of the recruit, 18 to 25, the power of accommodation is about = $\frac{1}{4}$ or 10 D. On exerting this fully then a near point just within 6″ may be obtained under the condition above named. Eyes with higher degrees of M. than $\frac{1}{12}$ will be able to obtain still nearer points when the − 6″ lens is before them. Theoretically, therefore, the test of reading within

6″ with a dispersing lens of $-\frac{1}{6}''$ power should prove the existence of M. $= \frac{1}{12}$ or above, and would exclude M. less than $\frac{1}{12}$. But, practically, it has been found that myopes with M. no higher than $\frac{1}{14}$, or even $\frac{1}{16}$, about 2·750 or 2·50 D, by practice can read within 6″ with the $-6''$ lens, and their employment for deciding the presence of such high degrees of M. as $\frac{1}{12}$ or upwards, not being found reliable, was abandoned.

The present rule in the Austrian Military Medical Service, as regards the disqualification of M. for engagement in the army, is the following. A myopic recruit, with a far point of 12 inches or less, if he is able to read printed letters, or to recognise other characters, of $\frac{1}{3}$rd of a Vienna line in height and corresponding breadth at any distance from the eye with concave 4-inch spectacles, is to be rejected as totally unfit for military service without any further examination. The $-4''$ spectacles are to be close to the eye, care is to be taken that the recruit really looks through them, not under them, and a good light is to fall upon the print.

The conditions described afford a proof that the degree of M. of the person under observation is not less than $\frac{1}{12}$, though it may be higher. Supposing the M. $= \frac{1}{12}''$, there would be Ac. at the age of the conscript about $\frac{1}{4}''$, so that the excess of refraction above Emmetropia, and the dynamic refraction of Ac., together would be equal to $+\frac{1}{3}''$. He could obtain a near point for reading at 3 inches distance from the eye without the glass. If then a $-\frac{1}{4}''$ lens be applied to the eye, the Ac. will be neutralised, and there will remain $+\frac{1}{12}''$, or M. $= \frac{1}{12}$. Suppose the far point distance of distinct vision without a glass appeared to be 6 inches from the eye, or, in other words, the M. was alleged to be $\frac{1}{6}$. The mode of proceeding if practised would equally afford a decided proof of its truth, if the statement were correct. For a M. $= \frac{1}{6}$ with Ac. $= \frac{1}{4}$, would together amount to $\frac{5}{12}$, and $\frac{5}{12} - \frac{1}{4}$ would leave an excess of refraction, or M. $= \frac{1}{6}$. The concave 4-in. lens neutralises the Ac., and leaves the myopic excess of refraction to act alone. If the eye had been an emmetropic eye, and had assumed a distant point of 12 inches, employing for the purpose a portion of its normal Ac., it could no longer read at the distance named with a $-4''$ lens; the eye being emmetropic, and its full amount of Ac. neutralised by the lens, it would only be capable of adjusting parallel rays and seeing distant objects of suitable dimensions.

It is stated in the Austrian Military Instructions for the surgical examination of conscripts (1883) that "Many years' experience and very numerous trials have proved that a myope can only satisfy this test, if his myopia is above $\frac{1}{12}''$, which is laid down as the limit of fitness for military service."

Influence of Myopia on Military Service.—For an account of the practical effects of different degrees of M. in respect to the requirements of military service, see Chapter VIII. The regulations under which the faulty vision resulting from myopia is directed to cause the rejection of men seeking enlistment as recruits are also given in the same chapter.

HYPERMETROPIA.

Definition.—Overmeasure as regards the distance of the principal focus of the dioptric media of the eye in relation to the measure of the optic axis.—The refractive power of the eye, when in a state of repose as regards accommodation, is less than that which is necessary for forming clear images of objects upon its retina. Parallel rays from distant objects are not brought to a focus by the time they reach the retina, but would unite in a focus, if they were not stopped in their course, at a point beyond the retina; or, in other words, the retina is in advance of the principal focus of the eye. Only convergent rays can be focussed on the proper sentient layer of the retina.

Optical Conditions.—In H. the antero-posterior diameter of the eye is, as a rule, disproportionably short with reference to its refractive power. Similar optical effects would result from the refracting qualities of the dioptric media being too low in relation to the length of the same diameter, or both causes might be combined.

Causes.—H. is often congenital. It is not unfrequently due to hereditary conformation of the eye, and, like myopia, is often found to exist in several members of the same family. In cases where the hypermetropic state is found to be very marked, the eye appears as if it had been stunted in growth: it is usually diminutive in form and short in all its dimensions.

Similar optical effects to those which characterise H. may be induced by any circumstances that lead to flattening of the globe of the eye, or of one or more of its component structures; as removal of the crystalline lens by displacement or by operation; or flattening of the cornea, for example. It sometimes shows itself as age advances, becoming noticeable after the patient has arrived at full manhood, without any apparent cause beyond changes due to increased years. It is then associated with *presbyopia*. This form of H. has been designated by Donders *acquired* H., to distinguish it from *original* H., due to early ocular conformation. (See remarks under Emmetropia, p. 36.)

Farthest Point of Vision.—This is sometimes spoken of as *negative*, because the hypermetropic eye has no objective distant point of distinct vision. Only convergent rays can be brought to a focus on the retina, and such rays do not proceed from any natural objects—they can only be produced artificially, as by a converging lens. The Hc. eye has only a virtual distant point, and this is the distance of the focal point to which parallel rays would be produced after traversing the dioptric media if they could pass beyond the retina. In order that parallel rays may be focussed on the retina itself of the Hc. eye, they must be first altered in direction; they must have such a convergence given to them before entering the eye as would cause them, supposing them to be unaltered in direction by the action of any refracting media, to meet at the distance of the focus above named. The convex lens that would give this amount of convergency to the parallel rays proceeding from objects at infinite distance, makes up for, and will serve to represent, the deficient converging power in the eye itself, or, in other words, the amount or *degree of hypermetropia.* Hence the remote point of distinct vision of the hypermetropic eye has sometimes been described as being at a distance *beyond infinity* equal to the value of the negative lens representing the deficient convergent power which the addition of the positive lens supplies. This of course is a mere optical expression which is employed as a matter of convenience to signify the different remote points in different degrees of H.

Thus, if a + 2D lens supplies the necessary amount of converging direction to parallel rays that will enable them, in addition to the refracting power of the eye itself, to be brought to a focus on the retina of the hypermetropic eye, the remote point of vision of this eye may be stated to be − 2D beyond infinity.

Nearest Point of Vision.—This varies in position according to the degree of H., but is always farther off from the eye than it is in emmetropic persons at corresponding ages of life.

Symptoms.—When a person affected with well pronounced H. looks intently for a short time at small objects, as in reading and writing, the letters become blurred and seem to run into each other. The vision of distant objects is more limited in range than normal, though the patient himself often fancies he can see well at a distance. The hypermetropic eye, although one eye only is used in aiming at range practice, cannot adjust itself for distant objects, as in trying to hit the bull's-eye of the target at long-range rifle practice, without an amount of accommodatory or muscular strain proportionate to the degree of H., and still less for near objects, as the "back and fine sights" of the rifle. As part of the natural amount of accommodation possessed by the hypermetrope has to be employed for getting a less indistinct view of the distinct object, a less amount remains for use in the effort to rapidly adapt vision to the distance at which the nearer objects are placed. When both eyes are employed in looking at near objects, especially such as call for close attention, a sense of ocular weakness results, and fatigue and aching are quickly produced; the patient suffers from symptoms of *asthenopia* (see Asthenopia, p. 123). The symptoms above named are the more marked in proportion as the degree of H. is greater, and especially if the general health is deranged and the subject is debilitated in consequence of it.

Association of H. with Strabismus.—H. is not unfrequently associated with convergent strabismus, and this circumstance seems to arise in the following way. The hypermetropic eye being adjusted for convergent rays, and no such rays existing naturally, the accommodatory apparatus is subjected to a constant exertion, in order to obtain more convexity of the anterior surface of the lens, and thus to make up for the hypermetropic deficiency, and to lessen the diffusion and indistinctness of the retinal images of external objects. This exertion is increased in proportion as the luminous rays are rendered more divergent by objects being brought close to the face, as occurs in reading, and the strain is greater when the work at near objects is prolonged and frequently repeated. Hence its frequent appearance in hypermetropic children at the ages when they begin to learn to read and write. The patient, generally a child of early age, unconsciously tries to relieve the excess of this constant strain on the ciliary muscle by contracting the internal recti muscles to obtain the increased accommodation for near objects associated with convergence of the optic axes. The normal balance of action between the internal and external straight muscles disappears, and a state of constant convergence results, even when the eyes are at rest. Parallelism of the visual lines ceases to be obtainable. As the point for which such a patient is able to accommodate his vision does not agree with the intersection point of the visual lines under this convergence, but is situated further off, the images of an object in front of the face will not fall upon corresponding points of the two retinæ, and the inconvenience of double vision would result. Under these difficulties the young hypermetrope prefers a comparatively clear and easily obtained monocular image rather than confused binocular vision attended with so much effort. One eye is, therefore, caused to converge more than the other, and in this way one of the images, falling upon a less sensitive part of the retina in the deviating eye, is ignored mentally, or, in other words, ceases to exist so far as the sensorial part of the act of seeing is concerned. For a time monocular vision is carried on equally by each eye in turn according as the position of an object may dictate, but at last vision devolves principally on one eye while the other is almost constantly turned inwards. This change takes place more readily when one eye is naturally weaker than the other in respect to retinal power, or has a higher degree of H. than the other eye. These abnormal relations of the internal recti muscles at last become constant, and convergent strabismus is established. When strabismus has thus been acquired, its tendency to become permanent is increased by the fact that the deviating eye gradually becomes retinally still weaker, and loses sensibility from disuse. It is for the purpose of neutralising the ill effects of continued strain upon the accommodatory apparatus in the efforts to obtain accurate vision of near objects, that convex glasses are recommended to be constantly worn for the treatment of H.; and it is by these glasses neutralising the H. that the strabismus so often induced by it may be prevented when it is properly treated on being first noticed.

Manifest and Latent Hypermetropia.—As the Hypermetropic eye is not able even to bring rays from distant objects to a focus on the retina by its unaided refractive power, it supplements it by using some of its accommodatory power in order to obtain clear retinal images of the objects looked at. Still more powerfully does it exert its accommodation in order to see near objects clearly. This habitual association of the act of accommodation with the act of vision at all distances leads to the loss of voluntary power of separating one from the other. In early life when all the structures of the eye are very tractable, and there is plenty of Ac. to be spared, the whole of the H. may be concealed by the Ac. supplied, but as years advance, and there is less Ac. available, and a continual struggle to use as much as possible of this Ac. in association with convergence for obtaining distinct vision at a nearer distance, the H. becomes deprived of a portion of the help it had previously derived from the Ac., and the H. becomes more and more manifest. At last, late in life, there is no Ac. to be lent to it, and then the total amount of H. is rendered manifest. But until this period arrives the full amount of H. is not shown unless all power of accommodation is artificially removed. This can be done by producing complete ciliary paralysis through the agency of atropia. The power of accommodation being thus removed, that portion of the deficiency of refractive power which was supplanted, and so concealed, by its agency is rendered manifest. Hypermetropia, therefore, of ordinary degrees usually consists of a certain amount of deficiency of refractive power which is apparent while accommodation is exerted; and of another amount which, naturally concealed by accommodation, becomes apparent only when accommodation is artificially prevented or has disappeared from age. The former deficiency is known as Hm., *manifest hypermetropia;* the latter, as Hl., *latent hypermetropia.* Obviously H., or the total amount of refractive deficiency, is composed of Hm. + Hl. If the degree of H. be moderate, or the hypermetrope be very young, it may be entirely latent, that is, only apparent after paralysis of accommodation. H. may therefore sometimes exist without attracting attention. Usually, however, though slight in degree, and not noticeable at first, it becomes so increased by fatigue, especially as age advances, from continued occupation at near objects, or by muscular weakness when the general health is impaired, that the symptoms of H. become apparent, and the diagnosis of it is rendered sufficiently easy.

Subdivisions of Hypermetropia.—A further division of H. has been made by Professor Donders into (1) *absolute* H., in which the rays from distant objects are not able to be focussed on the retina, but their focus still lies behind it, even with the aid of full power of accommodation and the strongest convergence of the optic axes; *relative* H., in which the rays from distant objects can be brought to a focus on the retina by the exercise of accommodation and convergence of the optic axes combined; (3) *faculative* H., in which the rays from distant objects can be brought to a focus on the retina with parallel optic axes, either with or without convex glasses.

Diagnosis of H. may be effected subjectively by the following modes of observation: namely, (1) by external signs, (2) by test-types, (3) by spectacles, (4) by correction, and (5) objectively by the ophthalmoscope.

1. *By External Signs.*—The eye frequently has a general flat appearance and often seems smaller than normal, as if it had been stunted in its growth, so that, in consequence, the space beneath and between the eyelids is not filled out, as it is in a fully grown eye. Sometimes the iris may be observed to reach nearer to the cornea than usual, owing to want of depth in the anterior chamber of the eye, while

the pupil is inactive and relatively small. An abnormal hollowness of the space between the eyeball and outer canthus may also be generally noticed on drawing the orbicular coverings aside. The appearances just described are, however, occasionally absent, or only very slightly indicated in eyes affected with hypermetropic vision.

2. *By Types.*—If the hypermetropia be strongly marked in degree, Snellen's types cannot be read by the subject of it clearly at their regular distances without the aid of lenses ; but if moderate, he may be able to read the larger and more distant type for a time, but with more or less difficulty. The eye soon becomes fatigued and the letters indistinct. In trying to read, a tendency for the optic axes to converge may sometimes be noticed, and the patient will often be observed to squeeze the eyelids together for the purpose of contracting the interpalpebral fissure. The association of the internal recti muscles, with the aid drawn from the use of accommodation, explains the occasional converging aspect of the eyes in the efforts at reading. The reason why the larger and more distant types are perceived with less difficulty than the smaller and nearer type, is chiefly due to the fact that the accommodatory strain is increased in proportion to the proximity of objects, from the rays that enter the eye from near objects being more divergent in proportion to their nearness ; these troubles are greater in proportion as age is greater.

When types of smaller sizes are used, the hypermetropic person, if he be of the ordinary age of a recruit or soldier, will be generally observed to carry them nearer to his eye than the regulated distances in trying to read them. He will be able to distinguish them better when close to his eye than at a distance away from it. The patient does so because, with the great convergence of the optic axes when the object is close, he is better able to apply his accommodatory power to counteracting the difficulties of reading, which are due to his hypermetropic condition of vision ; and, in addition, because the retinal images of the letters are increased in size, and therefore more readily perceptible, while the circles of dispersion are not enlarged in anything like a corresponding proportion, owing to the pupillary aperture becoming smaller on the near approach of the letters to the eyes.

From this circumstance, in diagnosing by types, H., when excessive, may be mistaken for M. combined with amblyopia. Distant objects are seen indistinctly—type of moderate size has to be held close to the eye to be read—and very small type cannot be read at all, as happens in M. complicated with amblyopia. The diagnosis may be established, by the fact that in H. distant objects are seen more distinctly, and the moderately sized types can be read further off, with the aid of convex glasses, while the same glasses would produce exactly opposite results in M. But even without + lenses the diagnosis may be established, for it may be observed that in H. the larger types of Snellen may be read quite as well, if not better, as regards *relative* distance, than the smaller types, which would not be the case with M.

3. *By the Spectacles.*—Weak concave glasses make vision worse ;

weak convex glasses, when accommodation is not exerted, improve vision. If the power of the convex glass accord with the degree of H., and steps are taken to prevent any Ac. from being exerted, all else being normal, Snellen's 20′ types can be read at 20′ distance.

When the convex 10″ lenses are worn, the hypermetropic eye is able to read type of moderate size at a distance beyond 10″ from the eye without the use of atropine. The distance at which the type can be read will be increased when the power of accommodation has been previously taken away by paralysing the ciliary muscle with atropine.

4. *By the Ophthalmoscope.* (See page 71.)

5. *By Correction.*—When the true degree of H. is ascertained, if no complication exist, the proper convex lens for that degree will completely correct the abnormal condition. It supplies the refractive power, which is missing in the eye itself, and produces the same effect as if no such deficiency existed.

Expression of the Degree of H.—The degree of H. may be either expressed by the power of the convex lens which acts upon parallel rays, so as to give them the amount of convergence, which would cause them to meet at a similar distance to that of the virtual remote point of the hypermetropic eye, for rays having such a convergent direction on entering the eye would be caused to meet upon the retina; or it may be expressed by the power of the concave lens, which represents the amount of deficiency in refracting power of the eye relatively to emmetropia. The latter mode is the most convenient and simple. The H. will then be expressed by the amount of the defect, and not by that of the lens which corrects it. H. = 2 D or $\frac{1}{20}$ then signifies that the deficiency of refracting power in the eye is equivalent to and represented by a − 2 D or − $\frac{1}{20}$″ lens, and that this deficiency will be neutralised or corrected by a + 2 D or + $\frac{1}{20}$″ lens.

To Determine H. or the Degree of Hypermetropia; or, in other words, to ascertain the total deficiency of refracting power as compared with emmetropia, by means of the + 10″ or 4 D spectacles.

Having thoroughly paralysed the power of accommodation by the use of a strong solution of atropia, and noted the distant point of distinct vision of each hypermetropic eye, examined singly, with the + 10″ lens before it, deduct from the power of this lens the inverted value of the distant point, and the difference will give the degree of H. in the eye examined.

Example.—Suppose the distance point is found to be 15″, then H. $= \frac{1}{10} - \frac{1}{15} = \frac{1}{30}$.

Explanation.—Let x = the refracting power of the eye under examination; let a = the refracting power of an emmetropic eye; $\frac{1}{10}$ = the power of the lens to which the eye has been subjected; and $\frac{1}{15}$ = the power of the lens which would give the ascertained distant point of 15″ if the eye were emmetropic. The deficiency of the refracting power in the example given is therefore equivalent to the difference between a $\frac{1}{10}$ and a $\frac{1}{15}$ lens. This deficiency can only be in the eye itself, and its refracting power must obviously be increased to a corresponding degree to bring it to a par with an emmetropic eye.

Therefore $x + (\frac{1}{10} - \frac{1}{15}) = a$; or $x + \frac{1}{30} = a$; or $x = a - \frac{1}{30}$. H., the total deficiency of refracting power, is $= \frac{1}{30}$.

If the distant point of distinct vision with the + 10″ lens be infinite, then H. $= \frac{1}{10} - \frac{1}{\infty}$, or $= \frac{1}{10}$.

If H. be suspected to be in excess of this amount, a stronger lens than a + 10″ lens will be necessary to ascertain its degree by this method. The + 2″ lens employed with the ophthalmoscope is generally available to army medical officers for the purpose. If H. $= \frac{1}{6}$ the distance point of distinct vision with the + 2″ lens will be at 3″ for H. $= \frac{1}{2} - \frac{1}{3} = \frac{1}{6}$. This will probably be the highest degree of H. to be met with, unless the lens be absent either from accident or operation (aphakia). But it is absolutely necessary that only one eye be examined at a time, and that it should be atropinised, for the spasm of the ciliary muscle associated with the convergence required for so short a range would otherwise prevent a proper diagnosis being arrived at.

If it be only required to determine Hm., or the degree of manifest hypermetropia, in all moderate cases the same *modus operandi* as above described may be followed, and the previous use of atropia may be dispensed with. But each eye should still be examined singly.

To find the Correcting Lens.—The total deficiency of refractive power having been determined, it may be corrected by a lens supplying the amount of converging power which is deficient, providing no accommodatory power is exerted at the same time. In the first example given, a + $\frac{1}{30}$ or a 30″ convex lens will be the correcting lens, because it will supply the refractive power which has been proved to be absent.

The absence of this amount of refractive power was shown in the experiment already above explained. The action of the lens will be such that when the patient looks at distant objects, the parallel rays proceeding from them, in passing through the lens, will be caused to assume a converging direction before they fall on the eye; and the angle of convergence given to the rays by the action of the correcting lens will exactly correspond with that degree of convergence which is wanting owing to the hypermetropic formation of the eye itself. The parallel rays from distant objects will thus become focussed on the retina, and clear vision obtained without exercise of accommodation.

This is the general principle on which correction of H. is effected; but in practice several modifying circumstances have to be specially considered. The hypermetrope, when he is not under the full influence of atropia, cannot fully give up the Ac. which he has been accustomed to use constantly as a substitute for the deficient refractive quality of his eyes. Even when convex glasses are placed before his eyes they retain part of the Ac. to which they have been accustomed. If, therefore, convex glasses equivalent to a full extent of the H. be furnished, the eyes will be in the condition of myopic eyes, with an excess of refracting power for rays from distant objects. The recommendation of Professor Donders for the correction of H. was that glasses should at first be supplied equivalent in power to the total manifest H., together with one-fourth of the latent H. After a certain interval, if the glasses be constantly employed, the efforts of Ac. will become partially relaxed, but in time the use of the remaining Ac. will again cause symptoms of asthenopia. The glasses at first given can then be strengthened to the amount of another instalment according to circumstances of the Hl., and should the symptoms return after a further period of time has elapsed, the glasses may then be strengthened to the full amount of the H. The final adjustment, if it be satisfactorily borne, will place the subject of the H. in the same condition as an emmetropic person of corresponding age. The full amount of accommodatory power possessed by him will be rendered available for its normal purposes.

Influence of H. on Military Service.—The conditions under which H. disqualifies for military service in the British Army are explained in the chapter in which the authorised modes of conducting the visual examination of recruits and soldiers are explained. On all occasions in which spectacles are allowed to be worn by soldiers, as in range practice, and at the School of Musketry, the use of correcting lenses by hypermetropes, even though the H. may be very low in degree, is of great advantage. It takes off the strain of the Ac., which is always present when a hypermetropic eye is trying to see distant objects clearly without such assistance, while it sets free the Ac. for use at near objects, so that at target practice both far and near objects, such as the objects painted on the target, together with the fore and back sights of the rifle, are all seen more plainly and with less visual exertion and fatigue. The indistinctness of vision that H. entails, the ocular troubles that accompany it, and the constant increase of visual difficulty with increasing years, renders men with hypermetropic vision particularly incompetent for judging distance or for service as riflemen, especially in an army in which correcting glasses are not permitted to be worn.

ASTIGMATISM.

Definition.—A term signifying that the rays proceeding from a single point are not, after refraction, reunited in a single point. Applied to vision, it signifies a state in which there is inaccuracy of view from malformation and blurring of retinal images owing to the fact that although some of the rays proceeding from an object may be brought to a focus on the retina, other rays proceeding from it are not at the same time similarly focussed upon its retina.

Optical Conditions.—The refractive quality of the astigmatic eye is not alike in all its meridians, and, consequently, has no single focus. The eye may be emmetropic in one meridian, while in another it is myopic or hypermetropic; it may be myopic or hypermetropic in all its meridians, but the degrees of myopia or hypermetropia may be relatively different in them; and, lastly, it may be myopic in one meridian, while it is hypermetropic in the other. Occasionally the refractive quality will vary in one and the same meridian of the eye to such an extent as to interfere with clearness of view. The term *regular astigmatism* is applied to that kind of Ast. which depends upon dissimilar curvatures of different meridians of the eye; *irregular astigmatism* to that which depends on unequal curvature in one and the same meridian, or to excessive spherical aberration of rays.

Causes.—Congenital asymmetry of the anterior segment of the ocular globe, or of the cornea, of such a kind as to cause a greater curvature of one meridian compared with that of the intersecting meridian. The absence of perfect sphericity is sometimes recognisable on observing the cornea by lateral illumination. An abnormal position or unequal curvature or other structural peculiarity of the crystalline lens has been said also to be a cause of astigmatic vision.

In nearly every eye a slight difference exists between the refractive power of the vertical and horizontal meridians, the vertical meridian having usually a greater curvature, and, therefore, a shorter focal distance than the horizontal, but the difference between them is not usually sufficient to interfere with correct vision; an exaggeration of this difference, however, gives rise to the inaccurate vision and disturbing symptoms characteristic of astigmatism.

Symptoms.—Acuteness of vision is lessened both for distant and near objects. If of congenital origin, it will have been continuous and without much alteration in degree. The shapes of objects are altered in appearance, and some parts are seen more distinctly than others. If the image of an object be sharp and defined in one direction, it will be rendered indistinct by diffusion of rays in a contrary direction; or if the image be indistinct from diffusion in both directions, it will be still further confused by the blurring being more widely diffused in one than in the other direction. In reading, the letters appear badly printed. Objects presenting linear intersecting markings, such as patterns with crossed stripes, are comparatively strongly defined and darker in colour in one direction, while in the other they appear faintly marked; or the whole pattern may become more or less obscure from the diffused rays from one direction of lines spreading over the lines of the pattern in the opposite direction. The astigmatic subject manifestly cannot by any accommodatory efforts bring the rays which are differently acted upon in passing through the various meridians of the eye to a focus on the retina at one and the same time, and he therefore exercises his accommodation to obtain greater clearness of view, first in one meridian and then in the other, often in rapid succession, so that asthenopia is induced, and adds to the visual trouble of the patient. The greater the difference of refraction in different planes of the eye, in other words, the higher the degree of astigmatism, the more strongly marked will be the symptoms above mentioned. The more open the pupil of the eye, the more obvious to the patient are the effects produced by his astigmatism. Astigmatism is often associated with high degrees of abnormal refraction, both myopia and hypermetropia, but the ametropic condition with which perhaps it is most frequently associated is hypermetropia.

Retinal Images of Astigmatic Vision.—In consequence of the rays passing through the meridian of greatest curvature being brought to a focus earlier than the rays passing through the opposite meridian, diffusion of the rays composing the image of an object is an inevitable result. The rays passing through the meridian of greatest curvature will throughout their path towards their focus be more convergent than those through the meridian of least curvature, and a section of all these rays on a screen, placed perpendicularly to the optic axis, would have an elliptical outline with the shortest axis of the ellipse formed in the direction of the most convergent rays. When the more converging rays have been brought to a focus, the rays through the meridian of least refraction will still be in progress, and at this distance a linear image will result with its length in the direction of the rays of least convergence which have not yet been brought to their focus. After the more convergent rays have been brought to a focus, they will cross and pass onwards divergently, while the less convergent rays will be approaching their focus. Here the image will also be elliptical, but the short axis of the ellipse will be in the direction of the rays of least convergence. On these rays arriving at their focus, a linear image will result, with its length in the direction of the divergent rays which had crossed from the first focus. At a certain point the distances at which the boundaries of the crossed divergent rays, and those of the converging rays still advancing towards their focus, are separated from each other will be alike, and at this point, and this alone, the image on a screen, such as the retina, would be a circular image.

Amount of Astigmatism.—This is determined by the difference in refracting power of the two meridians of the eye in which the inequality of refraction is most marked. Whenever astigmatism exists, there must be one meridian in which the refracting force is greatest, and another in which it is least. These two meridians cross at right angles to one another or nearly so. They are the *principal meridians* of the astigmatic eye ; the intervening meridians varying in refractive power according as they approach one or other of the two principal meridians. The expression of the difference in refracting power of the two principal meridians, or the power of the lens which would remove this difference by making the two equal, therefore, at the same time expresses the amount of astigmatism in any particular eye.

Rays of light traversing the principal ocular meridian of relatively greatest curvature, and, therefore, relatively greatest refractive power, will be brought to a focus at some point anterior to the focus of the rays which have traversed the principal meridian perpendicular to it, or the one which has the least refracting power. The space between the foci of the two principal meridians is known as the *Focal Interval*. The greater the difference in refractive power of the two principal meridians, the longer will be the *focal interval;* the less the difference in refractive power between these meridians, the less will be the extent of the *focal interval.* The measure of the focal interval, or of the lens which will bring the two foci into exact coincidence affords another means of expressing the amount of astigmatism.

Estimate of Amount of Astigmatism.—The measure of the amount of astigmatism, or of the difference between the refractive powers of two opposite meridians of an astigmatic eye, must be calculated differently in different kinds of astigmatism. If (1) the eye be ametropic in one meridian only, the opposite being emmetropic, the amount of ametropia in the one meridian will express the amount of astigmatism ; if (2) the eye be ametropic in two opposite meridians, and the ametropia is like in kind, that is, if both meridians are myopic or both hypermetropic, but differing in degree in each, the *difference* between the ametropia of the two meridians will express the amount of astigmatism ; if, lastly (3), the eye be ametropic in the two principal meridians but the ametropia is unlike in kind, that is, if one meridian be myopic and the other hypermetropic, the *sum* of the two degrees of ametropia must be taken to express the amount of astigmatism or difference in refractive powers of the two meridians.

Three kinds of Astigmatism.— The three kinds of astigmatism referred to in the preceding paragraph are named : (1) Simple Astigmatism ; (2) Compound Astigmatism ; and (3) Mixed Astigmatism. In form No. 1 one principal meridian of the eye is emmetropic, while in another and opposite meridian there is either an excess or deficiency of refractive power ; in No. 2, in both principal meridians, either an excess or a deficiency exists, but in different amounts ; in No. 3 there is excess in one principal meridian, while in the opposite one there is deficiency of refractive power as compared with an emmetropic eye.

Diagnosis of Regular Astigmatism.—1. *By Lenses.*—Though the eye may be hypermetropic, or myopic, neither + nor - *centric* lenses of any power will correct the existing defective condition or materially remedy the absence of acute vision.

2. *By Lines.*—When the 20′ vertical and horizontal lines of Snellen, and the rows of separate square dots are placed in front of the eye, they are not seen with equal definition. When the vertical lines appear dark and defined, the horizontal lines will not be seen with equal clearness, and *vice versâ* when the horizontal lines are seen comparatively clearly, the vertical lines will appear hazy. If attentively observed, the indistinct dark lines appear lighter in colour than they are printed, while the white spaces between them appear to be darkened, the general effect being to produce a greyness of colour, as if the black and white lines were mixed together, or as if part of the black were spread over the white, and part of the white spread over the black objects. If the horizontal lines be indistinct at the same time that the upper and lower margins adjoining the white interspaces are undefined, the left and right

extremities of the lines will be sharp and distinct. On the contrary, the lines placed vertically which are seen separate and defined, appear very black in colour, without any blending with the white interspaces, but the upper and lower ends of the lines appear to be a little elongated, or present the appearance of a shadow extending beyond each of them.

The lines which are most blurred, and so seen most indistinctly, are those which are in a *contrary direction* to that of the most ametropic meridian of the eye of the observer. Lines on the other hand, in a direction corresponding with that of the most ametropic meridian, are seen distinctly if one meridian be emmetropic, or with relatively greater distinctness if both meridians be ametropic. Thus supposing an eye to be myopic in one meridian but emmetropic in the meridian perpendicular to this myopic meridian, the linear markings of any objects looked at by it will appear hazy and obscure, though defined at their ends in the direction of the emmetropic meridian; distinct, normal in intensity of colour, but elongated at their ends in the direction of the myopic meridian. Or supposing the whole eye to be myopic, but in different degrees in its principal meridians, lines seen in the direction of the less myopic meridian will appear to be the most indistinct and confused, those in the direction of the meridian having the highest degree of myopia will appear to be the least so. The same will be the relative appearances of objects seen by astigmatic eyes in which the defective refractive quality is hypermetropic in kind.

If the eye be myopic in one meridian but hypermetropic in the opposite one, lines parallel with the meridian in which the defect of refraction is greatest will be seen with most distinctness, while lines parallel with the meridian in which the defect is least will visually appear the most obscure. Thus the preponderating defect as regards form of the astigmatic eye, and the preponderating defect as regards visual effect, are always in opposite directions to each other. It follows, in practice, that the fact of lines being seen in a certain direction more obscurely than in the direction perpendicular to it at once shows the direction in which the astigmatic eye under observation is least ametropic; and, *vice versâ*, the direction of the lines seen most clearly indicates the direction in which the form of the eye in respect to its refraction is most defective.

The explanation of the visual effects just described is simple. Thus, taking the case in which an eye is myopic in one meridian and emmetropic in the opposite one, the eye being accommodated for the distance at which the vertical and horizontal lines of Snellen are placed, the rays of light emanating from every point in the lines parallel with the myopic meridian will be brought to a focus in front of the retina, and images of all these points will be confused by circles of diffusion, while the rays falling in the emmetropic meridian will be focussed in the plane of the retina and form clear images. Supposing the myopic meridian to be vertical and the horizontal meridian emmetropic, the diffusion will of course be in a vertical direction. Vertical lines will therefore appear shadowy and elongated at their upper and lower ends, but there will be no diffusion at their lateral margins, or in the direction corresponding with the horizontal meridian of the eye. The diffusion of the rays proceeding from each dark point upwards and downwards, on the surface of any vertical line, will be superimposed on the adjoining dark points of the surface, and the general blackness of the whole line will not be interfered with. The only visual defect as regards lines in the direction of the defective myopic meridian will, therefore, be the shadowy prolongation of the vertical ends of the lines; the remainder of the dark lines, and of the white interspaces, will be clear and defined. But as regards lines parallel with the emmetropic meridian, or approaching it in parallelism, the diffusion being still in the direction of the vertical myopic meridian of the eye, the upper and lower boundaries of the horizontal lines, both the black and the white lines, will become diffused vertically on the retina, while there will be no diffusion as regards the ends of the lines. The vertical diffusion of their images on the retina will thus cause the series of black and white horizontal lines to appear to be mixed up together, not only rendering their upper and lower borders undefined, but causing also a general grayness of colour over the whole series. The ends of the lines will, however, remain sharp and distinct, because there is no diffusion of their images in the horizontal direction. The same explanation is applicable to the cases in which both principal meridians are ametropic though in different degrees; the relative visual defects depend equally on the causes just explained.

3. *By a Circular Point of Light.*—When a small round opening is made in a dark screen and light admitted through it, if looked at by an astigmatic eye at a distance of a couple of feet or so, the cone of light appears elliptical in form, the direction of the ellipse varying as the eye approaches or recedes from the opening. Whatever may be direction in which at one distance the hole in the screen appears to be elongated, at some other distance from the eye the hole will appear to be elongated in another and generally in a contrary direction.

The variations in the apparent form of the small opening depend on the differences of distance for which the eye is accommodated. If the astigmatic eye is accommodated to the distance at which the small opening is placed, so as to bring the rays of light proceeding from it to a focus on the retina in one meridian, the opposite meridian will be relatively ametropic, and diffusion of the rays passing through it will result. Thus, taking for example an eye that is myopic in its vertical meridian and emmetropic in the opposite meridian, when the small hole is so placed that the light traversing it is brought to a focus on the retina in the emmetropic meridian, diffusion of rays will occur in the direction of the myopic meridian, and the point of light will appear to be elongated in that direction, the opening will be elongated vertically. If, however, the distance be such that the rays of light are brought to a focus on the retina in the line of the myopic meridian, the opposite emmetropic meridian will practically be rendered for the time ametropic, deficient in refractive power, and diffusion will occur in that direction. If the eye in its horizontal emmetropic meridian be accommodated for focussing on the retina rays of light coming from the distance point of the myopic meridian, the myopic meridian will have its distant point shortened, and diffusion will occur in that direction. The point of light will appear to be elongated vertically.

4. *By a Stenopæic Hole.*—When the stenopœic opening is placed in the visual line near the centre of the cornea, and the astigmatic eye looks through it at the vertical and horizontal lines of Snellen, they appear as sharp and defined, or nearly so, in all directions, as they do to an emmetropic eye.

5. *By a Stenopæic Slit.*—When an astigmatic eye looks through a stenopœic slit at an object, the rays of light proceeding from the object and passing through the slit will be acted upon by the dioptric media of the eye according to the kind and degree of ametropia of the meridian the slit coincides with. If the case be one of simple myopic or hypermetropic astigmatism, and the slit be placed in the direction of the emmetropic meridian, both vertical and horizontal lines will appear equally clear. If the slit agree with the ametropic meridian, there will be diffusion of rays in the direction of that meridian, and lines corresponding with the meridian perpendicular to it will be rendered visually dim and obscure. The proper correcting + or − lens, according to the kind of ametropia, will at once remove the confusion. If the slit be applied to any intervening meridian similar effects will occur in a modified degree, according to the position of the meridian. If the case be one of compound M. or H. astigmatism, and the slit be placed so as to correspond with either of the principal ocular meridians, the visual effect will be the same as if the case were one of simple M. or H. astigmatism of amount corresponding to the degree of ametropia of the particular meridian to which the slit is applied. If it be a case of mixed astigmatism, objects will be seen as they would appear if they were regarded by an eye with simple M. or H. astigmatism, according to which meridian the fissure is applied. In all cases a correcting spherical lens will remove the astigmatic effect produced by the application of the stenopœic slit. It should, however, be remembered that effects similar to those last described would ensue if the stenopœic slit were applied to a myopic or hypermetropic eye of the same degree of myopia or hypermetropia, but without any astigmatism.

Varieties of Regular Astigmatism.—All cases of regular astigmatism belong to one or other of six varieties of the three forms of Ast. before mentioned. They are the following :—

1. *Simple Myopic Astigmatism* (Am.).—One ocular meridian is myopic, the contrary meridian emmetropic. Parallel rays passing through the former meridian are brought to a focus in front of the retina ; through the latter meridian, in the plane of the retina.

2. *Simple Hypermetropic Astigmatism* (Ah.).—One meridian is emmetropic, the contrary meridian hypermetropic. Parallel rays

passing through the former meridian are focussed in the plane of the retina, through the latter meridian, have not attained their focus on reaching the retina.

3. *Compound Myopic Astigmatism* (M. + Am.).—Both principal meridians are myopic, but in different degrees. One meridian presents a maximum of myopia, the meridian at right angles to it a minimum. Parallel rays traversing the two principal meridians are all brought to a focus in front of the retina, but at different distances in front of it.

4. *Compound Hypermetropic Astigmatism* (H. + Ah.).—The two principal meridians are hypermetropic, but in different degrees. One meridian presents a greater deficiency of refractive power than the other. Parallel rays traversing each meridian would, if practicable, be brought to a focus at a distance beyond the retina, but the focal distances beyond the retina would be different.

5. *Mixed Astigmatism; Myopia Predominant* (Amh.).—Both principal meridians are ametropic, but the anomalies of refraction are opposite in kind. Myopia in one meridian is mixed with hypermetropia in the contrary meridian, but the myopia predominates.

6. *Mixed Astigmatism; Hypermetropia Predominant* (Ahm.).—This variety is similar to No. 5, with the exception that hypermetropia, instead of myopia, predominates.

The amount of astigmatism in each of the foregoing six varieties will vary according to the difference between the maximum and the minimum of refraction in the two principal meridians. Such variations are very numerous. Of the three forms of astigmatism to which the six varieties belong, *i.e.*, the simple, compound, and mixed forms of astigmatism, the compound is most frequently met with in practice.

Examples of Regular Astigmatism.—The following will serve as examples of the six varieties of astigmatism. Their correction will be explained afterwards.

1. (Am.)—Vertical meridian myopic. M. = + 2D or $\frac{1}{20}''$. Horizontal meridian emmetropic. Amount of astigmatism, or the difference in refraction of the two principal meridians, or Am. = + 2 D or + $\frac{1}{20}''$.

2. (Ah.)—Vertical meridian emmetropic. Horizontal meridian hypermetropic, H. being — 2 D or — $\frac{1}{20}''$. Amount of astigmatism, or Ah. = — 2 D or — $\frac{1}{20}''$.

3. (M. + Am.)—Vertical meridian myopic = + 4 D or + $\frac{1}{10}''$, horizontal meridian myopic = + 2 D or + $\frac{1}{20}''$. Difference in refraction between the two meridians, or the amount of astigmatism, or Am. = + 4 D — 2 D = + 2 D or + $\frac{1}{20}''$.

4. (H. + Ah.)—Vertical meridian hypermetropic. H. = — 2·50 D or — $\frac{1}{16}''$; horizontal meridian hypermetropic = — 7 D, or nearly — $\frac{1}{6}''$. Difference in refraction between the two meridians, or the amount of astigmatism, or Ah. = — (7 D — 2·50 D) = — 4·50 D or — $\frac{1}{9}''$.

5. (Amh.)—Vertical meridian myopic = + 1·50 D or + $\frac{1}{26\cdot6}''$,

horizontal meridian hypermetropic, H. being $= - 1\cdot0$ D, or $\frac{1}{40}''$. The amount of astigmatism, or difference in refractive power of the two meridians, or Amh. $= + 1\cdot50$ D *added* to $1\cdot00$ D, $= + 2\cdot50$ D, or $+ \frac{1}{16}''$.

6. (Ahm.)—Vertical meridian myopic $= + 1\cdot0$ D, or $\frac{1}{40}''$; horizontal meridian hypermetropic $= - 1\cdot50$ D or $- \frac{1}{26\cdot6}''$. The difference in refractive power of the two meridians, or the amount of astigmatism, or Ahm., is, therefore, the same as in example No. 5, viz., $-(1\cdot50 \text{ D} + 1\cdot0 \text{ D}) = - 2\cdot50$ D or $-\frac{1}{16}''$.

In the foregoing examples, the vertical and horizontal meridians have been named as the two principal meridians of refractive defect, because it is in these directions, or nearly in these directions, that the refractive anomalies in astigmatism are most frequently found. But the anomalies of refraction may be found in any other of the ocular meridians, and it is essential to determine the precise inclination of the astigmatic meridians in every instance under notice before the correction of the astigmatism becomes possible.

To Determine the Direction of the Principal Ametropic Meridians in Astigmatism and their Degrees of Ametropia.—Various descriptions of test objects have been arranged for determining the direction of the principal ametropic meridians in cases of astigmatism. Of these probably the most convenient are, firstly, circles or semicircles, having radii of lines disposed at certain intervals, and marked by figures at the circumference which indicate the number of degrees into which the circumference is divided by them; or secondly, series of letters formed by lines placed at various angles of inclination, such as those known as "Pray's types."

If a circle be employed, a horizontal line dividing the circle into two semicircles, or if a semicircle, a line forming the base line of the semicircular arc, is marked 0 at one extremity and 180 at the other, while the line bisecting this is marked 90. The intervening radial lines are marked according to the number of degrees of the circumference included between them.

The letters of Pray's types are formed of thick dark lines, with white interspaces of the same dimensions. There are letters with the lines disposed in a vertical direction, others have the lines horizontal, and others with the lines inclined at various angles between these two directions.

In using these astigmatic test objects, the person under observation is placed at a distance of 15 or 20 feet from them, the objects being placed on a level with the face, and so that the light may fall on them. Note is then taken of the particular line, or particular letter, which appears most distinct to the astigmatic eye. If one of the lines or letters is seen without any blurring or confusion, it is apparent that the case is one of the simple form of astigmatism, and that the principal ametropic meridian is in the direction of the line or letter which is seen clearly. Let the line seen clearly be a vertical line, or the letter of Pray's types which is composed of vertical lines, the vertical meridian of the eye is ametropic, the horizontal emmetropic. If now a + and − cylindrical lens of one dioptric be successively passed before the eye with the axis of the lens held at right angles to the ametropic meridian, it will settle the question as to the nature of the astigmatism, whether it be myopic or hypermetropic. In the instance supposed, the axis must be horizontal. If the astigmatism be myopic, a −, if hypermetropic, a +, cylindrical lens will render all the other lines of the dial, or letters of Pray's types, more dark and distinct. A succession of lenses of the kind thus indicated may then be passed before the eye until the lens which entirely neutralises the ametropia, shown by all the lines and letters being clearly seen, is met with. The power of this lens being known, the nature and degree of the astigmatism will be equally known.

If, on regarding the dial or types, none of the lines or letters appear totally free from reduplication or blurring, although some have more definition than others, the case is one of compound, or mixed, astigmatism. The direction of the line or letters seen least hazily is noted, and the inclination of the ocular meridian of chief refractive defect is then known. Proceeding as before, a weak spherical + or − lens will indicate the nature of the ametropia in this meridian. The spherical lens which completely clears the line of indistinctness in the chief ametropic meridian shows the amount of ametropia in this meridian, and at the same time reduces the case to one of simple astigmatism. A weak + or − cylindrical lens, with the axis perpendicular to the inclination of the chief ametropic meridian, will show the nature of the ametropia in the other principal meridian, and a succession of trials with such lenses will show the amount of the ametropia by noting the lens which corrects it. If the cylindrical lens correspond in refractive quality with the quality of the spherical lens which corrected the ametropia in the chief meridian, the case is one of compound astigmatism; if the cylindrical lens be of opposite quality to the spherical lens, the case is one of mixed astigmatism. Thus supposing, for example, the person under observation sees the horizontal line of the dial or letter formed of horizontal lines least indistinctly, the principal meridian of chief ametropic defect is shown to be in that horizontal direction, the principal meridian with least ametropia is shown to be vertical. On trying with + and − spherical lenses of low power, a + lens increases the definition of the horizontal line. The ametropia of the vertical meridian, or meridian of least ametropia, is shown to be hypermetropia. A + 1·25 D spherical lens completes the definition of the horizontal line. The ametropia of the vertical meridian is shown to be H. = 1·25 D. The case is now reduced to one of simple astigmatism. A low power + cylindrical lens, axis vertical, lessens the indistinctness of the vertical line. The ametropia is therefore shown to be of the same nature in both principal meridians; and the case is shown to be one of compound hypermetropic astigmatism. On trial, a Cyl. + 2·50 lens, axis vertical, clears the vertical, and now with it and the + 1·25 D spherical lens together, the lines in all directions are cleared. The case is shown to be a case of compound hypermetropic astigmatism, Ah. vertical = – 1·25 D, Ah. horizontal = – 3·75 D. Or, as another example, the lines in a vertical direction being seen with least indistinctness, and the chief vertical ametropic meridian being shown to be vertical, a + 1 D spherical lens renders the vertical lines quite distinct. The horizontal ametropia is shown to be hypermetropia = – 1 D. It is presumed that steps have been taken to prevent, by the use of atropine, the exercise of accommodation on the part of the patient, or otherwise the hypermetropia in the horizontal meridian might be neutralised by its exercise. On trial, a – cylindrical lens is found to lessen the blurring of the horizontal lines. The ametropia in the vertical meridian is positive in quality, opposite to the quality of that of the horizontal meridian, and the case is shown to be one of mixed astigmatism. A – 2 D cylindrical lens, the spherical + 1 D lens being retained, renders horizontal and all the other lines clear. The case is thus proved to be one of mixed astigmatism, with vertical meridian myopic = + 2 D, and horizontal meridian hypermetropic = – 1 D.

Correction of Regular Astigmatism.—The correction of the first two varieties of regular astigmatism—(1) simple myopic astigmatism, and (2) simple hypermetropic astigmatism—when the nature and degree of the ametropia in the ametropic meridian have been determined, is at once effected by a suitable cylindrical lens. The axis of the lens must be placed in the direction of the visual defect, or, in other words, of the emmetropic meridian. The examples before given of these two varieties will therefore be corrected as follows:—

Ex. 1.—(Am. = + 2 D, or + $\frac{1}{20}$″.) Vertical meridian myopic, + 2 D; horizontal, emmetropic. A Cyl. – 2 D, or Cyl. – $\frac{1}{20}$″ lens, with the axis horizontal, corrects the Am., and renders the whole eye emmetropic.

Ex. 2.—(Ah. = – 2 D, or – $\frac{1}{20}$″.) Vertical meridian emmetropic; horizontal, hypermetropic – 2 D or – $\frac{1}{20}$″. A Cyl. + 2 D or Cyl. + $\frac{1}{20}$″ lens, with the axis vertical, corrects the Ah., and renders the whole eye emmetropic.

The correction of the compound and mixed forms of astigmatism may be effected in either of two ways. The astigmatism, or the difference between the two principal meridians, may be first rectified, and the remaining ametropia corrected by a suitable spherical lens; or the case may be in the first instance reduced to the simple form of astigmatism, myopic or hypermetropic, as the state may be, by an appropriate spherical lens, and the astigmatism then corrected by a proper cylindrical lens. The latter is probably the shortest method. The degrees of ametropia in the two principal meridians being known, whether in one of the varieties of the compound or of the mixed form of astigmatism, the correction of either meridian by a proper spherical lens will leave that meridian emmetropic and the other meridian alone ametropic. The case will then be one of simple myopic, or simple hypermetropic, astigmatism. If the meridian possessing the relative maximum of refractive power be so corrected, the remaining meridian will be rendered hypermetropic; if the meridian having the relative minimum of refractive power be corrected, the remaining principal one will be left myopic. The application of a suitable cylindrical lens will then complete the correction as shown in Exs. 1 and 2.

To illustrate this in the correction of the examples of compound and mixed astigmatism already given:—

Ex. 3.—(M. = + 2 D + Am. = 2 D.) Vertical meridian myopic + 4 D or + $\frac{1}{10}$″; horizontal meridian myopic + 2 D or + $\frac{1}{20}$″. A spherical — 2 D lens will render the horizontal meridian emmetropic, and reduce the refraction of the vertical meridian to a myopia of + 2 D. The case will then be similar to Ex. 1, and a Cyl. — 2 D or Cyl. — $\frac{1}{20}$″ lens, with the axis horizontal, will complete the correction.

Ex. 4.—(H. = — 2·50 D + Ah. = 4·50 D.) Vertical meridian hypermetropic — 2·50 D or — $\frac{1}{16}$″; horizontal — 7 D or — $\frac{1}{6}$″. A spherical lens + 2·50 D will render the vertical meridian emmetropic, and leave the horizontal meridian hypermetropic 4·50 D, or — $\frac{1}{9}$″. The case will then be similar to Ex. 2, simple hypermetropic astigmatism, and a Cyl. + 4·50 D or + $\frac{1}{9}$″ lens, with the axis vertical, will complete the correction.

Ex. 5.—(Amh. = 2·50 D.) Vertical meridian myopic + 1·50 D or + $\frac{1}{26·6}$″, horizontal meridian hypermetropic — 1·0 D or — $\frac{1}{40}$″.

A spherical — 1·50 D or — $\frac{1}{26·6}$″ lens will render the vertical meridian emmetropic, and leave the horizontal meridian hypermetropic — 2·50 D. A Cyl. + 2·50 D lens, with the axis vertical, will complete the correction.

Or a spherical + 1·0 D or + $\frac{1}{40}$″ lens will render the horizontal meridian emmetropic, and leave the vertical meridian myopic + 2·50 D. A Cyl. — 2·50 D lens, with the axis horizontal, will complete the correction.

Ex. 6.—(Ahm. = 2·50 D.) Vertical meridian myopic + 1·0 D; horizontal meridian hypermetropic — 1·50 D.

A spherical + 1·50 D or + $\frac{1}{26·6}$″ lens will render the horizontal meridian emmetropic, and leave the vertical meridian myopic + 2·50 D. A Cyl. — 2·50 D lens, with the axis horizontal, will complete the correction.

Or a spherical — 1·0 D or $\frac{1}{40}$″ lens will render the vertical meridian emmetropic, and leave the horizontal meridian hypermetropic — 2·50 D. A Cyl. + 2·50 D lens, with the axis vertical, will complete the correction.

It is obvious from the foregoing illustrations that two methods can be practised for reducing each variety of compound, as well as of mixed, astigmatism, to a condition of simple astigmatism. Either the meridian in which there is the relative maximum, or the one in which there is the relative minimum, of ametropia, may be corrected by a suitable spherical lens in order to effect the reduction. If the minimum be selected, as in the examples given of compound astigmatism, the remaining ametropic meridian retains its original kind of ametropia, but in a lessened degree. If the maximum of ametropia be corrected, the nature of the ametropia in the remaining principal meridian will be changed, and spherical and cylindrical lenses of opposite refractive conditions will have to be employed in the total correction. In mixed astigmatism, the remaining ametropic meridian, after the reduction to the simple form, may be either myopic or hypermetropic, according as one or other of the principal meridians has been corrected to reduce it to the simple form. Generally the mode of correction in which the conditions of refraction are simplest in kind, and least in degree, best answer the object in view. The creation of a new and opposite kind of defect in the remaining meridian should be avoided in all cases when practicable; while the plan which corrects one meridian and at the same time lessens the defect in the other, should be aimed at in all instances in which the reduction of a complicated to a simple form of astigmatism is under consideration.

There is a third mode of correcting compound and mixed forms of astigmatism, by neutralising the ametropia in each of the two principal meridians by suitable cylindrical lenses. The axes of the lenses will have to be placed at right angles to each other. Such bi-cylindrical lenses present practical difficulties in their manufacture and adjustment, and are consequently rarely employed in astigmatic correction.

Diagnosis and Correction of Irregular Astigmatism.—Irregular astigmatism being usually due to superficial alterations of form, resulting from inflammatory affections or other lesions of the cornea, some indications of the disease to which the eye has been subjected, are the general accompaniments of this form of astigmatism, such, for example, as cicatrices of corneal ulcers, faults of curvature, corneal opacities, and other abnormal conditions, which may be readily observed by lateral illumination of the cornea, or by direct ophthalmoscopic examination. Not only is the visual acuteness found to be impaired owing to the imperfect transmission of light due to these changes, but objects looked at by the patient are seen deformed. Straight lines appear wavy, and differ in depth of colour in some of their parts. Keratoscopy exposes the irregularity of the corneal curvature, by the manner in which the lights and shadows follow each other in succession, when the reflecting mirror is gently rotated on the axis of the handle which supports it. No forms of lenses, whether spherical or cylindrical, correct the deformity of such objects or restore normal acuteness of vision, although the deformity is less, and acuteness of vision frequently improved, when the access of rays of light is limited by the application to the eye of a stenopœic opening.

Influence of Ast. on Military Service.—It may be readily understood from considering the nature and effects of astigmatism, that it is an optical condition which must seriously interfere with the accurate performance of some of the most important duties of soldiers. The condition of myopia does not prevent the eye from seeing clearly at particular distances; hypermetropia interferes with good sight less at some distances than it does at others; but astigmatism renders vision indistinct at all distances. Objects not only appear indistinct, but they are more less altered in form; the extent and direction of their disfigurement varying according to the kind and amount of astigmatism in the eye which looks at them. The power of forming correct estimates of the distances of objects is consequently much impaired. In using a rifle, neither the object aimed at, nor the sights of the rifle itself can be seen accurately—their outlines are blurred, more in one direction than another, and their shapes are more or less altered. Moreover, this faulty state of vision is accompanied by an amount of ocular effort and persistent feeling of uncertainty regarding the true characters of objects that add materially to the difficulties of any astigmatic person whose duty it may be to observe objects before him with promptness and precision. A soldier who is astigmatic cannot, therefore, be relied upon for the proper discharge of his trust if he be placed on guard as a sentry—particularly on active service in the field, where alertness as well as a wide scope of view, and a well-defined recognition of all objects are often of essential importance.

The rules under which astigmatic defects of vision disqualify a recruit from acceptance for military service, and the regulated manner of determining the disqualification, will be found in Chapter VIII.

CHAPTER III.

Subjective and Objective Modes of Visual Examination.—Objective Assessment of Refraction.—Direct Mode of Ophthalmoscopic Diagnosis.—Conditions which Concern the Observer.—Those which Concern the Observed Eye.—Rays Emitted by an Emmetropic Eye.—By a Myopic Eye.—By a Hypermetropic Eye.—Effects of Foregoing on the Observer's Eye.—Application of Observations to Diagnosis.—Erect and Inverted Images.—Objective Diagnosis of Emmetropia.—Of Myopia.—Of Hypermetropia.—Astigmatism.—Measure of Ametropia by Refraction Ophthalmoscopes.—Manner of Employing them.—Diagnosis of Degrees of Myopia.—Of Hypermetropia.—On the Use of Refraction Ophthalmoscopes.—Keratoscopy.—Difficulties in Military Practice.—Appearances in Keratoscopy.—Keratoscopy with Concave Mirror.—Application in Practice.—Diagnosis of Degree of Myopia or Hypermetropia.—Measure and Correction of Astigmatism.—Keratoscopy with Plane Mirror.

Subjective and Objective Modes of Visual Examination.—The methods of determining the visual acuteness and refractive conditions of the eye hitherto described have depended in a great degree on the description by the person under observation of his own visual impressions. The subject under examination has told the surgeon what he could see, or could not see, under given circumstances. Reliance has necessarily had to be placed by the examiner on the honesty and correct description by the person under examination of the subjective phenomena that have occurred to him. If the person who has been tested has only been actuated by a desire to assist the examiner in his investigations, and has answered the tests put to him intelligently, the conclusions arrived at will be correct and sure; but if, intentionally or otherwise, the replies given to the examiner and the statements made by the person examined have not been in accordance with the person's real impressions, then the conclusions arrived at may be false. The accuracy of the conclusions may be tested by increasing the number of tests and varying their nature; but these proceedings occupy more time than frequently can be spared for the purpose. If, therefore, modes of examination can be practised, in which there is no need for the participation of the person under examination, in which the surgeon's own observations of the eye and its appearances under certain conditions, will suffice to reveal to him its refractive quality, and, if ametropic, its amount of ametropia, it is evident that such sources of fallacy as have just been referred to will be altogether removed. If, moreover, satisfactory results can be attained rapidly by an objective examination of the kind alluded to, then obviously the gain will be very great, both to the surgeon and patient, and especially to the surgeon when large numbers have to be examined within limited periods of time, as often happens in military practice. It is not to be wondered at then, that during the last few years a great amount of attention has been given to objective methods of exploring and determining ocular states of refraction, especially abroad in countries where the system of conscription is in force, and the numbers of conscripts to be examined, and the amount of false assumption or exaggeration of visual defects is far greater than British military surgeons ever have to deal with. As a general rule, a large proportion of conscripts for Continental armies would avoid military service if they could, and hence naturally have a tendency to exaggerate defects when they exist, or to make it believed that they exist when they do not exist, while, as a general rule, in a system of voluntary enlistment, just the reverse holds good, and the recruits do their best to show their fitness for service. It is obviously comparatively easy for a surgeon to determine whether a recruit's power of sight is up to a given standard when the man is doing the utmost he can to show his sight at the best; while it is a very difficult matter to prove that the quality of vision of a conscript is up to the required standard, when the man is trying to counteract the surgeon's efforts, unless the surgeon is sufficiently expert to determine the question by objective observation.

Objective Assessment of Ocular Refraction.—Ophthalmoscopic observation of the fundus affords very useful assistance to medical officers in enabling them to establish a diagnosis of the refractive condition of an eye in doubtful cases. If the subject's vision be really defective owing to ametropia, the presence and kind of ametropia after a little practice, and even the degree of the defect, can be determined by its means. The determination of the degree of visual acuteness by the methods previously described will indicate the amount of the alleged disability, and as, if any attempt at simulation be practised, a high degree of defect is likely to be assumed, the ophthalmoscopic examination will resolve all doubt on the subject, without the person under observation having any power to interfere with the conclusion at which the surgeon may arrive.

Both the direct and indirect methods of ophthalmoscopic observation can be used for ascertaining objectively the refractive state of an eye, but the former method is more reliable and useful. The direct mode of examination in which the mirror alone is employed can be applied in two ways, viz., by using it for observation of an illuminated part of the fundus, or particular object in this illuminated portion; or by using it for observation of the shadow by which the illuminated part is bounded. This latter application of direct examination is known as "*Keratoscopy*," or sometimes "*Retinoscopy*."

In order to judge not merely the quality of refraction, but to determine the degree of ametropia when ametropia exists, other expedients, in addition to the simple use of the concave mirror, are necessary. The expedients in ordinary use are mechanical arrangements for applying any required correcting lens to the aperture of the mirror by means of "*refraction ophthalmoscopes*," or the application, as in keratoscopy, of a series of trial lenses in front of the eye under examination. An explanation of each method follows.

ASSESSMENT OF AMETROPIA BY DIRECT OPHTHALMOSCOPIC OBSERVATION OF THE FUNDUS.

Ophthalmoscopic Diagnosis—Direct Method.—In this proceeding the ordinary concave mirror alone is employed. It is understood that the examining surgeon is himself emmetropic, or renders his eye emmetropic by correction through a suitable lens placed in the clip at the back of the mirror. The surgeon arranges himself so that the mirror, through the sighthole of which he makes his observations, is at a distance of 18 inches or more from the eye under observation, the light having its usual relative position to the patient and observer. For precise observation, especially in cases where there is reason for suspecting an attempt at simulation, it is well that the patient be placed under the influence of atropine. If this should not be convenient or considered desirable, then the eye of the patient should be directed to some distant point so that its accommodation may be relaxed as far as possible during the examination.

Rays Emitted by an Emmetropic Eye.—In applying this method it is to be remembered that the rays reflected from the illuminated retina of the emmetropic eye have such directions given to them in traversing the successive refractive media that they pass outwards from the emmetropic eye as parallel rays—that is, all the reflected rays emitted from each point of the retina after leaving the eye travel in a direction parallel with the axial ray belonging to that point.

Rays Emitted by a Myopic Eye.—The rays reflected from the retina of the *myopic* eye pass away from the globe as convergent rays, that is, all the rays from any one given illuminated point of the retina, instead of being parallel with the axial ray belonging to that point, converge towards it and meet upon it at some point. This meeting point is the remote point of distinct vision of the eye under observation, and its distance from the eye will depend upon the degree of myopia. The higher the degree of myopia, the more the rays converge, and, as a result, the nearer to the eye their meeting point. The point on the retina from which the reflected rays start, and the point at which they meet in front of the eye are conjugate foci, and in the case of a retinal object being regarded, a real and inverted image of that object will be formed in the position of the conjugate focus situated in front of the eye. This aërial image will be larger than the object from which it is projected.

Rays Emitted by a Hypermetropic Eye.—The rays reflected from the retina of the hypermetropic eye pass out of the globe as divergent rays, that is, instead of approaching toward the axial ray as described in the myopic eye, they diverge from it. The greater the deficiency of refractive power in the eye under observation, or, in other words, the higher the degree of hypermetropia, the greater will be the angle of divergency from the axis of the cone of rays. If these divergent rays were prolonged backwards they would meet at a point behind the retina, and at the distance of this point an erect, enlarged, virtual image of an illuminated retinal object would be formed.

So far then as an eye looking through the sighthole of the mirror is concerned, the rays falling on it will be parallel if the eye under observation from which they proceed be emmetropic, convergent if they come from a myopic eye, and have not yet reached their meeting point; and divergent if they come from a myopic eye after they have met and crossed, or if they come from a hypermetropic eye.

Effect of Rays from an Emmetropic Eye on the Observer.—The observer being understood to be emmetropic, the effect produced on his vision by rays having the several directions named, will vary according as he exerts accommodation or does not exert it. Being emmetropic, if no Ac. be exerted, his eye is adapted for focussing parallel rays and he will be able to see objects on the retina of the emmetropic eye under observation; but if Ac. be exerted and his V. adapted to the distance of the retinal object, he will not be able to see it with definition, because his eye will then be adapted for focussing divergent rays, while the rays emitted by the Em. eye and falling on his own are parallel rays.

Effect of Rays from a Myopic Eye on the Observer.—If the eye under observation is myopic, the clearness of view of the fundus will not only depend on the fact of Ac. being exerted or otherwise, but will also be influenced by the relative position of the examining surgeon and the position of the punctum remotum of the eye under examination. If the observer be placed so as to be within the remotum of the myopic eye under examination, and the emitted converging rays have not met and crossed before reaching the observer's eye, a clear image of a retinal object cannot be formed on the observer's retina. His eye is adapted for focussing parallel rays if no Ac. be exerted, and will be adapted for divergent rays, if

Ac. be exerted, while the rays reaching it under the conditions named are convergent rays. If the observer be placed so as to be outside and beyond the remotum of the observed eye, so that the emitted converging rays will have met and crossed before arriving at the observer's eye, then, under such circumstances, by accommodating for the distance of the meeting point of the rays from the observed myopic eye, he will see the image formed at this point as distinctly as if it were the object itself instead of its image. The emitted rays having crossed, fall on the observer's eye as diverging rays, and by the assistance of a suitable amount of Ac. they are brought to an exact focus upon his retina. The higher the degree of myopia the sooner will the emitted rays meet, and the nearer to the eye will be the aërial image of the fundus.

Effect of Rays from a Hypermetropic Eye on the Observer.—If the observed eye be Hc., as already mentioned, the emitted rays have a divergent direction, and fall upon the observer's eye as divergent rays. Now, if the observer accommodates for the apparent origin of these divergent rays, that is for the virtual remote point of the eye under observation, he will be able to bring the divergent rays to a focus on his retina and thus obtain a clear view of the objects on the fundus of the observed eye. The divergence is neutralised by the observer bringing his Ac. into action. If the observer cannot exercise sufficient Ac. for the purpose, or, in other words, if the virtual remotum of the observed eye be within the near point of distinct vision of the observer, clear vision of retinal objects on the fundus of the Hc. eye will not be obtained.

Application of Observations to Diagnosis.—The observations just described suffice to show whether the eye under examination is emmetropic or ametropic. The fact that no object on the fundus is defined, if any Ac. be exerted, proves that the eye is emmetropic; the fact that objects are defined when Ac. is exerted, proves that it is ametropic, and further, if the eye be myopic, that the remotum of the myopic eye is within the range between it and the distance of the observer. But more precise knowledge of the nature of the image seen by the observer is necessary in order to define the exact nature of the ametropia that is dealt with. This information is obtained in the following manner.

Although the observer takes a position at a distance of a foot and a half to two feet from the patient at starting, he may find that he has to vary the distance considerably before obtaining a clear view of the fundus. He will then move himself backwards and forwards, so as to increase or lessen the distance, according to need, until a clear view of a part of the fundus is obtained. If the eye under observation be emmetropic, and the observer finds a difficulty in relaxing his Ac., he will have to bring the mirror close to the eye of the patient before he can obtain a view of the fundus. When the observer's eye is brought thus close, all Ac. relaxes spontaneously, and the parallel rays emitted from the emmetropic eye can then be focussed on the retina of the observer as easily as if they proceeded from an object at infinite distance.

Erect and Inverted Images.—The observer, as soon as he has obtained a clear view of the portion of the fundus before him, fixes upon a retinal vessel as a mark of observation. A vessel proceeding from the optic papilla forms a convenient mark, as it is conspicuous by contrast with the background over which it passes. Moving his head to one side, the observer watches the apparent movement of the retinal vessel he has selected as a mark. If the object regarded follow in its apparent movement the same direction as the head of the observer—if the observer on moving his head to the right sees the vessel move to his right also, he knows that he is looking at an upright image; if, on the other hand, the object in its apparent movement follows a direction opposite to that of the observer's head—if the observer on moving his head to the right sees the vessel move to the left—he knows that he is looking at an inverted image of the object he has taken as a mark.

Objective Diagnosis of Emmetropia. Applying the observations just described if the observer, accommodating for the distance of the eye under examination, fail to obtain a distinct image of a retinal vessel, the eye may be regarded as neither myopic nor hypermetropic, but emmetropic. The conclusion will be rendered complete if the observer, carrying the mirror close to the eye he is examining, and no longer exerting accommodation, is then able to see a clear enlarged image of a portion of the fundus, and if this image proves itself to be an erect image by moving in the same direction as the observer moves his head.

Objective Diagnosis of Myopia.—If the observer, with the mirror at 18 inches or farther, sees a distinct image of a portion of the fundus, and, marking a particular vessel, finds it move in the opposite direction to that in which he moves his head, it is evident that he has a myopic eye before him. The image that he is seeing is an inverted image formed at the remotum of the eye under examination. If the observer's near point of distinct vision is beyond the range of distance between his eye and the image, the image will not be so distinct as it will become when he moves himself farther away from it. If the remotum of the myopic eye be farther off than the distance at which the observer can usefully employ the mirror for illumining the eye—a distance of 3 feet or more—no distinct image will be seen, and if a vessel can be distinguished it will move in the same direction as the observer's head, for the reflected rays emitted from this feebly myopic eye will not have crossed before they have reached the eye of the observer.

Objective Diagnosis of Hypermetropia.—If the observer with the mirror at 18 inches or farther sees an image of a portion of the fundus while accommodating for its apparent distance, and marking a particular vessel, finds it move in the same direction as that in which he moves his head, the conclusion is that he has a hypermetropic eye before him. The image is seen more distinctly as the observer approaches the eye under examination until he has arrived at 5 or 6 inches from it. The objects seen do not appear so enlarged as they do in the emmetropic eye when the observer's eye is brought close to the observed eye, but the chief distinction between the condition of Em. and H. is to be found in the fact that no image can be seen in the emmetropic eye at a distance of 6 or 8 inches, or further off, unless all accommodation is suspended, while in the hypermetropic eye the image is seen when accommodation is exerted in proportion to its distance and the degree of the defect.

Objective Diagnosis of Astigmatism.—The same indications may be turned to account in determining the existence of astigmatism. The indications will vary in the two principal meridians in kind and degree, according to the nature and amount of astigmatism presented. In mixed astigmatism the indications will be contrary in one meridian to what they are in the opposite meridian; they will correspond with those which characterise the myopic condition in one meridian, while they will agree with those distinguishing the hypermetropic condition in the opposite meridian. If no astigmatism be present in the observed eye the retinal vessels radiating over the fundus are seen in all directions with equal distinctness.

ASSESSMENT OF AMETROPIA BY REFRACTION OPHTHALMOSCOPES.

Description of Refraction Ophthalmoscopes.—These opthalmoscopes are used for determining objectively the state of refraction of an eye on the same principles as those on which the direct method of observation just described by the concave mirror alone is based; but the mirror is furnished with a series of small convex and concave lenses with a view to determine not only the nature of any ametropia which may exist, but also to estimate its amount by ascertaining the power of the lens necessary for its correction. There are many forms of refraction ophthalmoscopes, differing in mechanical details, but in all the varieties the small correcting lenses are so arranged that they can be moved in rotation behind the mirror in such a way as successively to cover the sight-hole through which the observer looks at the eye under examination. There are usually two superimposed discs behind the mirror, each carrying a certain number of lenses, arranged circularly near its outer border, and each capable of being rotated independently into any position at the discretion of the operator. In the refraction ophthalmoscope sold as "Johnson's improved ophthalmoscope" the lenses are so arranged that in applying them only one refracting medium intervenes between the eye of the observer and the patient in all the lenses between − 1 D and − 10 D inclusive, and between + 1 D and + 8 D inclusive, while by the intervention of a second lens all the intermediate half dioptrics and higher powers up to − 29 D on the one hand, and + 23 D on the other hand, can be obtained. By this means, although twenty-one lenses are inserted in the two discs, a range of seventy lenses is obtained. Means are adopted for indicating at the back of the instrument the power of each lens brought before the aperture of the mirror. This ophthalmoscope, like others of the same class, is also supplied with two concave mirrors, one small and of short focus, the other large and of long focus. The small mirror has a diameter of seven-eighths of an inch and a focal length of 3 inches, the larger mirror a diameter of 1·4 inch and a focal length of 18 inches. They are so connected and pivotted that either can be instantly brought into position as required, and so supply a convenient mirror for direct examination close to the patient's eye, and a second, suitable for concentrating light on the fundus when used at a distance from the patient, as in the indirect method of examination or in keratoscopy. The smaller mirror is not flat, having its plane parallel with the plane of the revolving discs, like the larger mirror, but is set at an angle of 35°, and being made to rotate round its own axis can be turned to reflect the light from and in any direction required. The examining surgeon, instead of inclining the mirror, in order to obtain the fullest amount of light for reflection upon the eye of the patient, can effect the same purpose by rotating the mirror in its position, and at the same time avoid the inclination which would otherwise be given to the correcting lens relatively to his own line of sight. Whatever the position of the inclined mirror, the principal axis of the lens used for correction, and the visual axis of the observer, remain in one and the same line.

Manner of using Refractive Ophthalmoscopes for Direct Observation.—The small mirror is brought uppermost. As it is inconvenient for the observer to use one of the disc lenses attached to the mirror for correction of his own ametropia in case he is ametropic, he must either wear suitable spectacles or take his own error of refraction into account when he finds the lens which appears to correct the ametropia of the observed eye. If the observer be myopic, he must subtract the power of the lens equivalent to his degree of myopia from the lens which corrects an observed myopic eye, or must add it to the power of the lens which corrects an observed hypermetropic eye. If the observer be hypermetropic, he will have to deduct the power of the lens representing his degree of hypermetropia from the power of the correcting lens of a hypermetropic patient; he will have to add it to the power of the correcting lens of a myopic patient. It is necessary also that the accommodation of the observer as well as of the eye under observation should be in abeyance. Holding the instrument upright, he then places the mirror as near to the eye to be examined as can be managed, and rotates the mirror until he has so adjusted it as to concentrate the light on the fundus of the eye under examination. At this close distance to the examined eye there will be little, if any, difficulty as regards the exercise of accommodation by the examiner, and his eye will be adapted for focussing parallel rays. The light should be placed to the outer side of the eye to be examined, and about 6 inches behind it. For this observation it is less embarrassing for the examiner to place himself on the same side of the patient as the eye to be examined—on the right side for the right eye, on the left side for the left eye. The patient should be caused to turn his eye upwards and inwards in such a direction as will bring the optic entrance in line with the observer's line of sight, and to look as far away as practicable in order to keep his accommodation relaxed. The handle of the instrument should be held in the hand of the observer, but his forefinger should rest on the margin of the wheel by the action of which the principal disc is turned, when, if it be the left hand, by pressing the disc from above downwards, or from left to right, the correcting lenses will be brought into position in an ascending series, and by pressing it in a reverse direction in a descending series. The value of each lens as it comes into place is shown on the back of the instrument; the figures being coloured red for the convex, white for the concave lenses. The indications will then be as follows :—

Diagnosis of Emmetropia.—An enlarged and upright image of the optic entrance and retinal vessels is seen. The details of the image are clear, and are not rendered more clear by the intervention of any + or — lens. It is necessary to be sure to prove that the eye is not hypermetropic, for in the hypermetropic eye the image may be clearly seen by the observer if he use his accommodation and so focusses the emitted divergent rays. If, however, the eye is emmetropic the intervention of a + lens of low power will change the direction of the parallel rays as they fall on the eye of the observer into converging rays, and the emmetropic observer will then fail to get an image as clear as he did when the rays fell on his eye as parallel rays.

Diagnosis of Degree of Myopia.—The observer sees only a blurred and indistinct image of the fundus, for the rays falling on his eye have a converging direction. On rotating the disc and bringing the concave lenses in succession over the sight-hole the image becomes gradually clearer, and is at last rendered distinct. The refractive excess of the myopic eye is then neutralised, and the rays emitted from it after passing through the correcting lens fall on the observer's eye as parallel rays. They are changed into the same direction as if they were received directly from an emmetropic eye. The power of the first, or least dispersing, lens which produces this result expresses inversely the degree of the myopia. The image may remain distinct, although a dispersing lens of higher power is placed behind the aperture of the mirror, but in this case part of the action of the higher concave lens is neutralised by the observer exercising a proportionate amount of his accommodation.

Diagnosis of Degree of Hypermetropia.—The image of the fundus is seen clearly with the mirror alone, if the observer can exercise accommodation so as to adapt his sight to the apparent distance from which the divergent rays emitted by the eye under observation take their start. The observer tries the intervention of a + lens of low power. If the image remains clear the eye is hypermetropic; the divergency of the rays emitted by it is lessened, but the observer still accommodates for the apparent distance of the virtual remotum of the eye under observation, and so obtains a clear image of the fundus. The lenses are successively increased in strength until the image of the fundus is rendered more or less indistinct. The rays falling on the eye of the observer are now not divergent nor parallel, but have been rendered convergent. The refractive deficiency of the eye under observation has been more than supplied, and the eye rendered slightly myopic. The lens expressive of the degree of hypermetropia will, therefore, be either the last used, the strongest converging lens under which the fundus was seen clearly, or will be between it and the lens which has rendered the image of the fundus more or less confused.

Remarks on the Use of these Instruments.—Much practice is necessary before an estimate of the degree of ametropia can be formed even with approximate exactness in some instances. Errors are apt to arise from the observer not relaxing his accommodation completely or from failing to determine the precise limits of the maximum of distinctness of the images seen by him—at what point the distinctness is greatest, or at what other point the distinctness begins to be lessened. Other sources of error occur in this method of examination. Theoretically the correcting lens ought to be situated at the anterior focus of the eye under observation, about half an inch in front of the cornea, but from the form of the instrument and the position in which it must be held for reflecting the light upon the pupil, the lens behind the mirror is practically an inch or so beyond this distance. The greater the distance of the lens from the anterior focus of the eye, and the higher the degree of ametropia of the patient, the less precise will be the estimate furnished by the power of the correcting lens.

The allowance to be made on account of the various sources of error just referred to can only be arrived at after long practice with the instrument. The difficulties are increased when the refracting ophthalmoscope is employed for determining the relative differences of refraction in a case of astigmatism.

ASSESSMENT OF AMETROPIA BY KERATOSCOPY.

Keratoscopy.—Keratoscopy is a name given to a mode of determining the refractive condition of an eye, which is now much resorted to in civil hospital practice, as it can be employed independently of active assistance on the part of the patient, can be accomplished rapidly, and the end attained in most cases with adequate precision, notwithstanding the presence of amblyopia. Keratoscopy does not depend upon observation of the cornea itself, as the term would seem to imply, but upon variations in the aspects and relative movements of certain lights and shadows seen within the pupillary disc under special ophthalmoscopic arrangements. The term Retinoscopy is sometimes applied to the same method of observation, but this term fails to distinguish it from other modes of ophthalmoscopic observation of the retina, and the meaning of *keratoscopy*, though faulty as an expression, is universally understood.

Keratoscopy in Military Practice.—The practice of keratoscopy requires not only a mirror, either concave or plain, but also a complete case of trial lenses. As such trial cases do not form part of the equipment of military hospitals, military surgeons will rarely be able to avail themselves of this method of observation for deciding the qualities of vision in particular cases subjected to their judgment, but must resort to other proceedings described elsewhere in this manual. Whenever trial cases of lenses are available, however, by private means or otherwise, keratoscopy, when the art has once be acquired, will be found to possess many advantages, especially in cases complicated with amblyopia or astigmatism. To be expert in the application of keratoscopy the surgeon must be prepared, as in other modes of estimating amounts of error of refraction objectively, to devote considerable time and attention to its practical acquirement.

Arrangements necessary for Keratoscopy.—The pupil of the eye to be examined having been dilated, and the accommodation paralysed, by the use of atropine, when its employment is not for any special reasons objectionable, the patient, seated in a dark room with the lamp placed well behind him, is directed to look at a distant object just above the surgeon's head. The surgeon, having previously corrected any error of refraction peculiar to himself by a suitable lens at the sight-hole of the mirror, seats himself at a distance of about 3 or 4 feet from the patient, and lights up the eye to be observed by means of the mirror held vertically. The most convenient mirror for the purpose is a concave mirror whose principal focus is at a distance of from 1 foot to 18 inches.

Appearances in Keratoscopy.—Observing steadily the illumined intra-pupillary disc, the surgeon rotates slowly the mirror on the axis of its handle, and on doing this the appearance of a dark shadow may be noticed at one of the lateral borders of the red disc, and, if the rotation be continued, the shadow will advance until it obscures the whole space of the disc. At a certain interval half the disc will appear illumined and half appear shaded. If it be the half of the disc to the left of the observer which is obscured, while the half to his right is illumined, the shadow is advancing from left to right, as seen by the observer; if the shadowed and illumined portions be reversed in position, the shadow travels from the observer's right toward his left hand, so that the shaded part always marks the side from which the shadow travels, and the illumined part that to which it is travelling. The exposed border of the shadow will sometimes be straight, sometimes more or less crescentic in outline; its intensity also, and rate of movement with reference to the movement of the mirror, will vary in different cases. It will be seen from the arrangement of the light and from the distance at which the observer holds the concave mirror, that the converging rays reflected from the mirror will meet and intersect in the air, and that, having crossed, they will then fall on the eye as diverging rays proceeding from the point of intersection, and will ultimately be brought to a focus, or will approximate to a focus, and will form a more or less defined image on the retina according to the refractive quality of the media of the eye under examination by which they have been acted upon in their passage. The part of the retina outside the illuminated image will be in shadow. It is this shadow, dark by contrast with the illuminated part of the fundus, the movements of which, after the image and its surrounding shadow have been acted upon in returning through the refractive media of the eye toward the eye of the observer, the observer examines in keratoscopy. The more true and defined the image on the retina, the brighter will be its edge and the darker and more distinct the border of the shadow; on the other hand, the more the image is confused by circles of diffusion, the more weak will be its illumination though more extended in area, and the less defined and the more crescentic in outline will be the border of the shadow. It follows, therefore, that it is in the lower degrees of ametropia, where there is least diffusion, that the most defined shadows are presented to view, and *vice versâ*, that in the higher degrees of ametropia the shadows are less marked in character and outline.

Nature of Keratoscopy.—It will be observed from what has been stated that the direction in which the light and shade alternate, or, in other words, the direction from which the shadow comes and to which it goes, does not depend solely upon the direction of movement of the mirror, but, with the same movement of the mirror, will vary according to the refractive quality of the eye under observation. In keratoscopic observation, therefore, the surgeon first takes into account the direction in which he moves his mirror, and, secondly, the direction in which the shadow follows the reflected light within the pupillary disc; whether the path of the shadow is direct, or follows the light in accordance with the movement impressed on the mirror, or whether its path is inverted, the shadow following the pupillary light in the opposite direction to that of the movement given to the mirror.

Estimating Ametropia by Keratoscopy.—These constitute the principal points to be noted so far as concerns the determination of the refractive quality of the eye under observation; but, if the eye be ametropic, certain other points already alluded to have to be noted in forming an estimate of the amount of the ametropia. The form of the edge of the shadow, whether linear or crescentic; the kind of movement, whether slow or relatively quick; the degree of brightness of the illuminated portion of the disc, and the definition of the edge of the shadow; all assist in affording means of estimating the amount of ametropia. There is, however, only one method of determining the degree of ametropia with precision, viz., by the use of trial lenses placed in succession before the eye under observation until the keratoscopic signs of the ametropia are caused to disappear or changed in character.

Application of Keratoscopy in Practice.—The surgeon, patient, and light being in the relative positions and at the distances before described, and the patient's gaze being fixed on a distant object, especially if atropine has not been used in order to prevent exercise of accommodation, the surgeon lights up the eye to be observed. The eye of the patient should be so turned that the light neither falls on the macula lutea nor on the optic papilla, but to the inner side of both or on the retina below. The mirror is now rotated, and the order of movement of the light and shadow in the pupillary disc watched. The following will be the indications according to the nature of the movements observed :—

1. If the light and shadow follow the direction of the mirror, or in other words if their movement be direct, the eye is myopic, and the degree of M. indicated is higher than 1 D. The mirror, held at a distance of 3 or 4 feet, is outside and beyond the distant point of distinct vision of the examined eye.

2. If, under the same circumstances, the light and shadow move in a direction opposite to that of the movement of the mirror, in other words, if their movement is an inverse one, the eye is probably hypermetropic, but either emmetropia, hypermetropia, or myopia of a low degree may be present. If it be a case of weak myopia, the shadow is light, not strongly marked ; the mirror is within the distance of the distant point of distinct V. of the eye under observation ; the degree of M. is lower than 1 D.

To Ascertain Amount of M. or H.—A trial spectacle frame is placed on the patient, and according to the nature of the ametropia diagnosed, either + or — lenses are placed in succession before the patient's eyes, until the shadow is caused to reverse its direction under the keratoscopic observation or becomes hardly noticeable. If the shadow has its direction reversed, the ametropia is more than neutralised, and weaker lenses must be applied until this reverse movement ceases, and the shadow is simply deprived of definition. The lens which produces this result gives approximately the measure of the ametropia. If the result is not similar in opposite meridians of the eye, astigmatism exists, and each meridian will have to be dealt with separately in the manner just described.

Estimating Degree of Myopia.—It will be observed that in diagnosing and estimating M., the distance of the observer relatively to the distant point of distinct vision of the eye under observation, or the degree of M., has an important bearing in the keratoscopic appearances. If the observer holds the mirror farther off than the remote point of V. of the eye under observation, the movement of the shadow is direct, as already mentioned ; but if the observer were to place himself within the distance of the remotum of the eye under observation, the movement of the shadow would be reversed ; while if he were to place himself at the precise distance of the remotum, no defined shadow would be observable.

If, therefore, the observer place himself at 1 metre distance or beyond, and the shadow more directly with the mirror, the eye under observation has M. higher than 1 D, while if the shadow move inversely as the mirror moves and the eye is myopic, the degree of M. must be less than 1 D. In the higher degrees of M. the refractive condition is easily recognised ; in the lower degrees of M., such as M. of 1 D or lower, the M. is not readily distinguished from emmetropia, or a low degree of H. ; for the movements of the shadow bounding the image formed at such a distance from the eye under observation are hardly recognisable. But if on placing before the observed eye a + lens of low power, such as one of half a dioptric, the direction of movement of the shadow is seen to be changed—from moving inversely to moving directly—there is no doubt the case is one of low myopia, and that the small addition of the +0·5 lens has given it the usual character of M. of a higher degree. If it were a case of hypermetropia, so small an addition would not have sufficed to neutralise the hypermetropic deficiency of refraction.

Estimate and Correction of Astigmatism by Keratoscopy.—The correction of astigmatism by keratoscopy is effected on the same principles in each of the meridians, but the process is one which requires considerable practice in order to accomplish the desired results with accuracy. If a shadow in a vertical direction differ in definition or intensity, or show a different rate of movement from the shadow in the horizontal direction, or if the shadows assume an oblique direction, it may at once be assumed that astigmatism exists which requires correction. Each meridian is corrected separately, and the eye afterwards tested with the combined spherical and cylindrical lenses before it, and when the ametropia appears to be neutralised in all directions, it may be assumed that the glasses are correct. If the shadows are not vertical and horizontal, but have an oblique direction when the mirror is moved in the ordinary way, the obliquity of the astigmatic meridians will be in a corresponding direction.

Keratoscopy with the Plane Mirror.—If under similar circumstances to those just described the surgeon uses a plane mirror at a distance of 3 feet or beyond, on observation of the eye under examination the effects will be found to be the reverse of those met with when the concave mirror was used. The shadow will follow the same path as if the observer were watching the retina itself, or vessels on the retina, and observing the manner in which these objects move relatively to the movements of his own head in direct illumination of the observed eye. If the eye under examination be myopic and the myopia exceed 1 D, the shadow will move inversely as the mirror is moved; if the shadow move directly in accordance with the movements of the mirror, the eye is either emmetropic, hypermetropic, or is myopic inferior in degree to 1 D. In the emmetropic condition the shadow has only moderate saturation, though it may be well defined; in hypermetropia, the saturation and definition of the shadow are increased in proportion to the increase in degree of H.; in myopia the definition and depth of the shadow also vary according to its degree. With M. higher than 1 D, the image of the illumined portion of the fundus and the shadow, which is a real image formed between the mirror and the observed eye, is well marked; with M. lower than 1 D, the image is erect and virtual, not formed in front of the mirror, and the shadow is wanting in distinctness and saturation.

CHAPTER IV.

Accommodatory Function of the Eye.—Act of Accommodation.—Demand for Ac.—Mechanism of Ac.—Power of Ac.—Expression of Amount of Ac.—Measure of Amount of Ac.—Region of Ac.—Association of Convergence and Ac.—Presbyopia.—Definition.—Optical Conditions.—Causes.—Diminution of Ac. with Age.—Abnormal Pr.—Symptoms of Pr.—Diagnosis.—Determination of Degree of Pr.—Examples.—Correction of Pr.—Range of Ac. in Presbyopic Vision.—Pr. with Myopia.—Pr. with Hypermetropia.

Accommodatory Function of the Eye.

The conditions previously described, viz., those of emmetropia, myopia, hypermetropia, and astigmatism, depend upon persistent qualities of eyes. It may be supposed that the quality of an eye, so far as concerns either one of the conditions just named, would remain the same whether the eye, if physically unchanged, be a living eye, or whether it be disconnected from the human body. It is simply a quality which is determined by the forms and refractive powers of the several dioptric media of the eye acting in concert, or of the whole of them together regarded as a single lens, relatively to the position of the retina.

The eye has the function, however, under certain circumstances of changing its refractive adjustment. If it were not so, the eye would be adapted for clear vision at one distance only, viz., that of its distant point. The emmetropic eye would only see objects clearly at infinite distance; the myopic eye at its limited distant point; the hypermetropic eye would not see objects clearly at any distance. This function, by means of which the eye is able to see objects clearly at different distances, is called the *accommodatory function*, or briefly, *accommodation*. The discharge of the function constitutes what is known as the *act of accommodation*.

Act of Accommodation.—This act is performed on all occasions when vision is transferred from a more distant to a more near object. If two pages of print are placed a few inches apart before the eye, with an opening in the more near page, the eye while reading through this opening the print on the more remote page is unable to recognise any of the words on the near page. To read the words on the near page, although they are closer, the eye, in common language, must "look at them;" and on reading them the eye ceases to be able to recognize the words on the more remote page, although they are within reading distance, and may be directly opposite to the eye. The same effects may be noticed in looking at a landscape through a pane of glass, and then at some small object on the glass itself. The term "looking at the object" here signifies performing the *act of accommodation*. If carefully observed, the act of accommodation will be noticed to be accompanied with a sense of muscular effort. If the parts concerned in the proceeding happen to be inflamed, as occurs in iritis and other morbid states, the act of accommodation is accompanied with considerable, often acute, pain; and one, among the other advantages of the use of atropine in the treatment of iritis, is that it stops the act of accommodation by temporarily paralysing the structures on which the function depends, and so averts the pain that would be caused by its exercise.

Demand for Accommodation.—The need for the exercise of accommodation increases in proportion to the proximity of objects, or, in other words, to the divergency of the rays proceeding from them which have to be brought accurately to a focus on the retina of the observer.

Mechanism of Accommodation.—The act of accommodation, which in ordinary optical instruments is effected by altering the mechanical adjustments subordinate to the lenses, in the eye is effected by changes in the form of the crystalline lens itself. The distance of the surface on which the images are received, the retina, from the front of the refractive media, the cornea, remaining the same, it can only be by increasing the refractive power of the eye, that the more divergent rays from nearer objects can still be brought to an exact focus at the distance of the plane of the retina. Various experimental observations have proved that the agent in affording this increase of refractive power is the crystalline lens; and, indeed, that this lens does become more convex and so more refractive in exact proportion to the increased nearness of objects looked at by the eye has been demonstrated by various investigators, and especially by Professor Helmholtz by means of his ophthalmometer. The anterior pole of the crystalline lens advances, while the diameter of its equatorial circumference is lessened, the whole anterior surface being thus rendered more convex and coming nearer to the cornea in proportion to the nearness of the objects to be observed. This convexity is lessened again when objects a little farther off are to be observed; and for objects beyond a distance of 20 feet or so, from which rays proceed in nearly parallel lines, the lens resumes the form which belongs to its state of repose. When no accommodation whatever is exerted, rays of light entering the eye, so far as regards the direction which they subsequently assume, are influenced by the stationary refractive quality of the eye alone; and although this permanent quality may be added to by the exercise of the function of accommodation, as just described, there are no means provided within the eye by which it can be lessened.

The production of the changes in the form of the lens is attributed principally to the action upon it of the ciliary muscle. The iris has ceased to have any power of action or has even been totally absent; the external ophthalmic muscles have all been paralysed; and yet the accommodatory faculty has remained apparently perfect. Therefore, this faculty could not have been dependent on the influence of any of these structures as was once supposed.

A further proof that the ciliary muscle is the agent, and the crystalline lens the anatomical structure acted upon by it, in the production of accommodation, is the fact that whatever paralyses the ciliary muscle, by paralysing the motive power, stops the faculty of accommodation; while the displacement or absence of the crystalline lens on which the ciliary muscle acts, equally arrests the faculty of accommodation. The use of atropine, and conditions of disease interfering with the nervous supply to the ciliary muscle by the third pair of nerves, stop the faculty of accommodation; it is equally arrested by removal of the crystalline lens in the operation for cataract, or by its dislocation from accidental injury.

It is supposed by some that the circular fibres of the ciliary muscle, contracting in the manner of a sphincter, exert through the medium of the ciliary processes and the unyielding fluid in the canal of Petit a pressure on the equatorial circumference of the lens, and thus cause it to change its form for accommodation; while my former colleague, Inspector-General Dr. Macdonald, R.N., has demonstrated an accessory annular muscle within the circular sinus, or canal of Schlemm, which may well be associated in this action. Although doubts still exist among many observers as to the precise mode of action of the ciliary muscle on the crystalline lens—some, indeed, believing that the contraction of the ciliary muscle induces an alteration in the tension of the Zonula Zinnii, and relaxes the capsule of the lens so as to permit the lens itself to expand by virtue of its elasticity,—yet there are none who any longer doubt that the changes of accommodation depend on changes of form in the crystalline lens, and few that these changes are principally due to the action of the ciliary muscle upon it.

Power of Accommodation.—The *total power* of accommodation corresponds with the degree in which the function of accommodation can be exercised, or, in other words, with the amount to which the eye is able to increase its refractive quality. The complete amount of power of accommodation is represented by the accommodation employed when the near point of distinct vision is obtained. As the position of the near point of distinct vision depends on the accommodatory power being exerted to its fullest amount, this near point also furnishes an index to the *limit* of the power of accommodation.

Expression of Power of Accommodation.—The power of accommodation exerted in order to obtain distinct vision at the nearest point at which an eye is capable of seeing objects clearly may be measured and expressed by the power of a converging lens, which, on being placed before the eye, will give clear vision at the same distance without the eye exerting any accommodatory power at all. If an eye be emmetropic, the stationary refractive power of its dioptric system is such that parallel rays of light proceeding from objects at infinite distance are brought to a focus on the retina, and while no accommodation is employed, it can only bring such rays to a focus at the plane of the retina as have a parallel direction with each other when they fall on the eye. It is evident, then, that a lens added to it which will represent the additional refractive power that the eye can obtain by bringing into play the whole of its accommodation, must be such a lens as will cause the rays of light proceeding from objects at the distance of the nearest point of distinct vision of the eye, after passing through the lens, to impinge on the eye as parallel rays. The eye otherwise would not be able to bring the rays to a focus on the retina. The principal focus of this lens must therefore be at the same distance as that of the nearest point at which clear vision can be obtained. The rays starting from this near point, or, in other words, from the principal focus of the lens employed, will then be rendered parallel when they reach the eye. If, for example, an emmetropic eye can obtain by the full exertion of its accommodatory power, clear vision of objects at a distance of 4 inches, or one-tenth of a metre from itself, then, without any accommodation being exerted, a + 4-inch or + 10 D lens, whose principal focus is at the same distance, will effect the same result. This lens, therefore, will represent and give the measure of the full amount of accommodation possessed by the eye under consideration. If the duodecimal or inch system of notation be employed, the power of the lens representing the measure of the accommodation exerted will be $\frac{1}{4}$; if the metrical system be employed, the power of the lens representing the measure of the accommodation will be + 10 D.

Measure of Power of Accommodation.—It is constantly a matter of importance in ophthalmic examinations to determine and define the amount of power required for adapting vision from an object at some known distance to another object at some known nearness, and Professor Donders gave the following formula by which it can be readily found and expressed :—

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}.$$

In this formula R is the measure of distance of the remote point for which the eye is primarily adjusted, whether expressed in inches or parts of a metre; P is the measure of the nearest or proximate point for which the eye becomes adjusted when accommodation is exerted; A is the focal distance of a convex lens which would so lessen the divergency of the rays coming from the proximate point P, that they would follow the same path, after passing through the lens, as was followed by the rays coming from the remote point R, without the lens; and $\frac{1}{A}$ is the power of this lens. It is obvious that the eye in transferring vision from any remote point, R, to any near point, P, must so alter its focal adjustment as to act on the more divergent rays from P exactly in the manner attributed to the supposed lens A, and must exert a *power of accommodation* equivalent to $\frac{1}{A}$. $\frac{1}{A}$ therefore represents and expresses the difference in the accommodation required for vision at P as compared with that required for vision at R.

Thus, to apply the formula to the example above given of an emmetropic eye adjusted for infinite distance in a state of rest, and capable of altering its focal adjustment by the exercise of accommodation, so as to see clearly small objects as near as 4 inches: $\frac{1}{A} = \frac{1}{4} - \frac{1}{\infty} = \frac{1}{4}$, or the power of accommodation will be equal to $\frac{1}{4}$. In other words, the eye, in altering its adjustment from clear vision at infinite distance, when no accommodatory exertion was required, to vision at a distance of 4 inches, has used accommodation, or, in other words, has increased its refractive power to an extent equivalent to a lens of $\frac{1}{4}''$ power, or of a lens whose principal focal distance is at a distance of 4 inches from its centre. Thus when the position of the near point of distinct vision in an emmetropic eye is found, the total amount of Ac. is also found. In the same eye, if vision be transferred from an object placed at 20 inches distance to another object only 10 inches off, the formula shows that the amount of Ac. employed in the proceeding, or $\frac{1}{A}, = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$.

In a myopic eye, whose farthest point of distinct vision in a state of rest is 12″, and whose nearest point of distinct vision by the exercise of accommodation is 3″, $\frac{1}{A} = \frac{1}{3} - \frac{1}{12} = \frac{1}{4}$, or the total power of accommodation is equal to $\frac{1}{4}$. In other words, this eye, in altering its adjustment for vision at a distance of 12 inches to vision at the nearer distance of 3 inches, has increased its refractive power to an extent exactly equal to the emmetropic eye quoted in the previous paragraph, which transferred its vision from an object at infinite distance to another at 4 inches distance, viz., to an extent equivalent to that of a lens of $\frac{1}{4}''$ power, or of a lens whose focal distance is 4 inches. In each case the power of accommodation exerted is $\frac{1}{4}$, or + 10 D.

To determine the amount of Ac. for a hypermetropic eye, the total amount of H., or refractive deficiency, must be first found, and subsequently, the position of the near point of distinct vision when H. is corrected. The lens which corrects H., added to the lens whose principal focus is at the same distance as that of the near point, gives the total amount of Ac. Thus if H. $= -\frac{1}{20}$, the correcting lens will be $+\frac{1}{20}$, or a + 20″ lens, and if the near point when this lens is in use be at 20 inches distance, an equivalent $+\frac{1}{20}''$ lens must be added, and $\frac{1}{A} = \frac{1}{20} + \frac{1}{20} = \frac{1}{10}$. A convex lens of 10″ focus represents the Ac. necessary for obtaining a near point of distinct vision at 20 inches distance for an eye that is hypermetropic $\frac{1}{20}$.

When the metrical system is used for expressing power of accommodation, instead of the formula $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$, the formula Ac. $= pD - rD$ will furnish the refractive power of the equivalent lens. Thus in the examples above given, as regards the emmetropic eye, in the first instance Ac. = 10 D − ∞ = 10 D, in the second instance, Ac. = 4 D − 2 D = 2 D ; as regards the myopic eye, Ac. = 13·33 D − 3·33 D = 10 D ; as regards the hypermetropic eye, Ac. = 2 D + 2 D = 4 D.

Influence of Age on Accommodation.—The power of accommodation is similar in all eyes that are healthy in condition, whatever may be their refractive qualities, at corresponding periods of life.

Region of Accommodation.—The range, or latitude, or region of accommodation, signifies the particular tract over which an eye can see clearly, extending from the most distant to the most near point of distinct vision; or, in other words, comprehends the space between the distant point of distinct vision and the near point of distinct vision throughout which an eye can adjust itself so as to obtain clear images of objects. As shown in the preceding paragraph, an equal power of accommodation may be exerted over regions which vary very greatly in regard to position and extent of space. In the first example a power of accommodation equal to a 4-inch lens is associated with a region of accommodation which extends from infinite distance to a near point at 4 inches distance from the eye. In the second example the same power of accommodation exists with a much more limited region of accommodation, viz., one whose limits are between a distant point of 12″ from the eye and a near point of distinct vision at 3″ from the eye,—that is, a region of 9 inches.

Although, as already stated, the *power* of accommodation is alike in all eyes of healthy condition at corresponding ages, the *region* of accommodation differs at corresponding ages in different eyes, according as they are emmetropic, myopic, or hypermetropic.

Association of the Internal Recti and Ciliary Muscles in Accommodation.—When an object situated in a plane midway between the two eyes, and at a short distance in front of them, is looked at, the two internal recti muscles, in giving the necessary direction to the two eyes for the visual lines to meet in the object, act concurrently with the ciliary muscles in their action for obtaining the amount of accommodation which is required to secure accurate vision of the object at the distance at which it is placed. Clear and disembarrassed vision of a near object can only naturally be obtained when the functions of convergence and accommodation are in due harmony. There is no reason for believing that the internal straight muscles have any specific influence on the production of accommodation, nor any influence beyond what results from their action in bringing the eyes into a favourable position for receiving the diverging rays proceeding from near objects, or, in other words, for effecting a right direction of the visual lines.

When the internal straight muscles are put into a condition of great tension for effecting a high degree of convergence they may, perhaps, act as a *point d'appui*, as it were, on which to base greater efforts on the part of the ciliary apparatus, and in this way they may lead to an increased amount of accommodation and to clearer images being obtained of the near objects under view. The general action, however, of the internal recti muscles, as regards accommodation, is an associated, not a controlling one. The extent to which the two functions are employed in their associated action is liable to variations. When the two eyes are directed to a small object at a fixed distance, and the object is seen clearly, under normal conditions the convergence and the Ac. may be assumed to be in precisely due proportion. But when two prisms of small refracting angles are placed before the eyes in the manner described at p. 32 (see Prisms), the object may still be seen with precision, so that while the degree of convergence is altered the Ac. remains unchanged. On the other hand, while looking at the same object, if instead of the prisms weak + or − glasses within certain limits are placed before the eyes, the object may still be seen clearly, so that now while the degree of convergence is unaltered, the amount of Ac. is changed. The Ac. relatively to the convergence is, therefore, not a constant quantity, and the relations between the two functions are found to differ in different persons. As, however, the convergence of the eyes increases in proportion as the object required to be seen is brought nearer to them, and the demand upon the accommodatory muscle must also increase at the same time, the actions of the internal recti and of the ciliary muscles are under normal conditions of necessity intimately and, for the most part, are almost proportionately associated. It is essential that the facts of the intimate association of these two functions when they are free to act in concert, and of the difficulty of converging the eyes without the accommodatory force associated with the degree of convergence concerned being involuntarily called into action, should be fully recognised, for they explain many phenomena in visual diagnosis which without this knowledge would not be understood.

If, under any circumstances, the correlation between the action of the ciliary muscles in accommodation and the action of the interni recti in convergence, be very largely disturbed, a painful and almost intolerable sense of strain is experienced as the result. This has been illustrated experimentally by Mr. Brudenell Carter in a very simple manner. Let a young person with emmetropic eyes put on convex spectacles of five dioptrics and attempt to read with them. The strain and tension of the eyes will soon become unbearable. He will be very nearly in the same condition as a person having myopia of five dioptrics who is reading at his distant point of distinct vision. He will be converging to a point at 8 inches distance, while there will be no demand for the exercise of accommodation. In the myope, his amount of myopia takes the place of accommodation at the distance named; the convex glasses replace it in the case of the emmetrope. On this Mr. Carter observes: "It may be shown by a simple experiment that this strain is not due to the convergence effort *per se*, but solely to the fact that the convergence effort is made during repose of the accommodation. If we combine with the convex lenses prisms with their bases inwards, of sufficient power to rest the convergence as well as the accommodation, reading immediately becomes easy. If we then give the same person concave spectacles, such that he is able to overcome them by accommodation, and bid him look at the horizon, the strain upon his eyes will again become unbearable. He will be exercising a good deal of his accommodation to overcome the glasses, but he will be exercising no convergence, because the distance of the object of vision requires that, for the sake of fusion, he should keep his visual lines parallel. We may relieve the strain instantly by placing before the concave lenses prisms with their bases outwards, which will call for a convergence effort in addition to the accommodation effort; so that we create strain by causing either function to be performed singly, and we relieve strain either by placing both at rest or by calling both into play." ("On Defects of Vision, &c.," Lond., 1877, p. 138.)

PRESBYOPIA.

Definition.—Vision of advanced age, characterised by being obscure for small objects at near distances. Diminished range of accommodation due to increase of age. The absolute "near point" of distinct vision is removed further than 8 inches from the eye, while rays from distant objects are still brought to a focus upon the retina, in the same way as they would be irrespective of the Pr.

Optical Conditions.—There is no defect as to the stationary refractive quality of the eye or, in other words, of the eye in its state of repose in simple presbyopia; it may be emmetropic, and neither concave nor convex lenses improve the sight for distant objects. But the necessary change of form of the crystalline lens cannot be obtained; or, in other words, the refractive power of the dioptric media of the eye cannot be increased by the exercise of accommodation to the extent necessary for bringing the more divergent rays from very near objects to a focus on the bacillar layer of the retina.

Causes.—Natural changes from age. The near point recedes in all eyes in regular progression with increasing age; the change is a normal one, and advances with advancing years. The recession of the near point commences early in life. The following table shows the decrease which takes place in the power of accommodation at various periods between 10 and 75 years of age expressed in dioptrics, and the recedence of the near point of distinct vision at corresponding periods of life shown in English inches.

TABLE showing the diminution in power of accommodation, and the corresponding changes in the distance of the near point of distinct vision, as years advance. (From Donders, but converted into Dioptrics and English inches.)

Years.	Dioptrics.	English inches.
10	14	2·85
15	12	3·33
20	10	4
25	8·50	4·70
30	7	6
35	5·50	7·33
40	4·50	9
45	3·50	11·50
50	2·50	16
55	1·75	23
60	1	40
65	0·75	53
70	0·25	160
75	0	—

This recession of the near point is solely attributable to diminution in accommodatory power. As already explained, exertion of this faculty is called for in proportion to proximity of objects or divergence of rays. The gradual decrease of this faculty seems to be due to the crystalline lens becoming more and more firm with increasing years, so that the same amount of alteration in its form cannot occur. It is doubtful whether changes in the structure and curvature of the cornea may not also assist in causing the difficulty of adapting the eye for near vision.

From the explanation just given of the nature and causes of presbyopia, it is evident that not only when an eye is emmetropic, or hypermetropic, but also if it be myopic, it may equally become subject to presbyópia from age. Whenever the actual near point of distinct vision becomes removed further than 8″ from the eye, presbyopia has arrived.

Abnormal or False Presbyopia.—Diseased conditions, such as interferences with the elasticity of the lens capsule by posterior synechiæ after iritis, morbid changes in the structure of the capsule of the crystalline lens or lens itself, paralysis, complete or partial, of the ciliary muscle, and any diseases inducing great constitutional debility, may increase the presbyopic condition temporarily or induce symptoms similar to those of presbyopia. Presbyopic vision resulting from these causes should be regarded as abnormal, and distinguished from True Presbyopia, the result of normal changes from advancing years or old age.

Symptoms.—Normal Presbyopia is not usually complained of by persons with emmetropic vision till after 40 years of age, generally not till 45 years. The degree of complaint will vary according to the size of the objects the subject of presbyopia habitually deals with. The presbyope says that, though he can see as well as formerly at a distance, he finds it troublesome, or even painful, to try and recognize small objects near him. In reading he has to remove the print farther and farther from his eye. Then, on account of the distance he has to hold the print, he cannot see the words accurately.

The difficulty is greater in the evening with artificial light than during the daytime with sunlight, and he sees best when he holds a candle or lamp close to the page of the book he is looking at.

The decrease in that perfect transparency of the principal dioptric media which characterises healthy eyes in the earlier period of life that takes place as age advances, and the haziness with more or less tinge of colour in them when age is far advanced, prevents ordinary sources of light from giving the full amount of contrast between the white and black parts of a printed page, or between the lights and shadows of other objects, and thus prevents the images of the objects themselves from being impressed on the retina with the same vividness as in former earlier years of life. This condition, together with the distance at which small objects have to be held, and, consequently, the lessened amount of light reflected from them at such a distance, combine to explain the difficulty old persons meet with in reading or doing fine work, without the assistance of a strong light upon the objects in view. One advantage in the correction of Pr. is that the need for such a strong light is considerably lessened, because, after correction, the print or other small objects can be seen clearly when they are brought near to the eyes.

The nearest point of distinct vision can only be attained by extreme exertion of the ciliary apparatus, and, when this state of tension is produced, it quickly causes fatigue. It is to obviate this annoyance that objects are removed further off than the actual near point, but then, if the objects are very small, their retinal images become too minute, and the light emitted by them too diffuse and too diminished for easy recognition. The objects are again brought nearer to the eye, the ciliary strain is again induced, and this course, on being persevered in, gives rise to ocular aching, super-ciliary pain, headache, and vertigo, until at last, a stop is put to the power of doing the fine description of work the patient is engaged in.

Diagnosis.—The age of the patient, with the usual evidences of the adjustment of the eye for parallel rays if the patient be emmetropic, as explained under emmetropia, and the distance of the near point, sufficiently distinguish presbyopia from any other affection. When either myopia or hypermetropia co-exists with presbyopia, there will be the evidences already described of these conditions in addition to the fact of the near point of distinct vision being distant beyond 8″ from the eye.

To Determine the Degree of Presbyopia.—As presbyopia is generally held, in accordance with the limit laid down by Professor Donders, to exist when the near point under binocular vision has receded beyond 8″ from the eye, the degree of presbyopia is determined by finding the focal power of the convex lens which will bring back the near point to 8″.

The amount of Pr. is the amount of the accommodatory power which has been lost from that which previously enabled the person to work continuously at fine work at 8″ distance from the eye without strain or fatigue, relatively to the remainder which now only admits of clear vision at some distance beyond 8″. The convex lens which will so add to the refractive power of the eye as to bring back the near point to 8″ substitutes itself for the accommodatory power which has disappeared from the eye itself, and therefore serves as an expression for the missing power, or, in other words, for the degree of presbyopia.

The refracting value of the required lens is found by using the formula which has been already explained as serving for an expression of power or latitude of accommodation, viz., $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$. It may equally be found, according to metric notation, by the formula $\text{Ac.} = p\text{D} - r\text{D}$. As $\frac{1}{A}$, or Ac., at the same time signifies the missing latitude of accommodation, Pr. may be substituted for it: so that $\frac{1}{A}$, or $\text{Pr.} = \frac{1}{P} - \frac{1}{R}$, or $p\text{D} - r\text{D}$. The proximate point P, or pD, is here 8″, or 5 D, because that is the near point for which a substitute for the missing accommodation is to be supplied, and to which the refractive power of the eye is to be adjusted.

The remote point, R, is the distance to which the near point has receded owing to presbyopia, or the distance up to which accommodation is missing.

Examples.—Suppose the near point has receded to 12″ distance from the eye; then Pr. $= \frac{1}{8} - \frac{1}{12} = \frac{1}{24}$, or 5 D − 3·34 D = 1·66 D (24·09″ Eng.) If it has receded to 24″ distance, then Pr. $= \frac{1}{8} - \frac{1}{24} = \frac{1}{12}$, or 5 D − 1·66 D = 3·34 D (11·97″ Eng.).

To Determine the Correcting Lens.—The same formula that determines the amount of accommodatory power which is missing, determines the focal power of the lens which must be added to the eye to act as a substitute for it. Thus in the example first given, in which the Pr. $= \frac{1}{24}$, a + 24″ lens, or a lens of 1·66 D, will neutralise the presbyopia; in the second example a + 12″ or 3·34 D lens. With the aid of the lenses named, the presbyopic $\frac{1}{24}$ and $\frac{1}{12}$ patients will be able to do fine work at 8″ distance from the eye as if the near point of distinct vision of the eye itself were at 8″ distance.

Power and Range of Accommodation in Presbyopia.—The power and range of accommodation of the presbyopic eye diminish in proportion as the presbyopia increases, or, in other words, in proportion as accommodation for near objects is lost. Thus in the emmetropic person whose remote point of distinct vision is at infinite distance, at 10 years of age the power of accommodation is $\frac{1}{2·85} - \frac{1}{\infty} = \frac{1}{2·85}$, or 14 D, at 20 years is $\frac{1}{4} - \frac{1}{\infty} = \frac{1}{4}$, or 10 D; at 30 years $\frac{1}{6} - \frac{1}{\infty} = \frac{1}{6}$, or 7 D; at 40 years $\frac{1}{9} - \frac{1}{\infty} = \frac{1}{9}$, or 4·50 D; at 50 years $\frac{1}{16} - \frac{1}{\infty}$, or $\frac{1}{16}$, or 2·50 D; at 60 is $\frac{1}{40} - \frac{1}{\infty}$ or $\frac{1}{40}$, or 1 D; and at 75 is 0. The power of accommodation is thus shown to be considerably lessened as age advances. While the boy of 10 years of age can increase his ocular refractive power to the amount of 14 dioptrics, the man of 30 can only increase it to 6, of 40 to 9 dioptrics, while at 75 the power of increasing refraction, or the accommodatory power, has disappeared altogether.

Presbyopia with Myopia.—As the power of accommodation is alike in all eyes at corresponding ages, and as the distant point of distinct vision is nearer to the myopic eye than it is to the emmetropic eye, it follows that the near point of distinct vision will be nearer to the myopic eye than it is to the emmetropic eye at corresponding ages of life. The near point will not recede beyond 8″ so soon in the myopic person as in the emmetropic person, or, in other words, presbyopia will appear later in life in the myopic person than in the person with emmetropic vision. Moreover, the presbyopia can only occur in myopic persons whose myopia is moderate in degree. If the myopia amount to $\frac{1}{8}$th, or 5 dioptrics, presbyopia can never occur; for the distant point of distinct vision being at 8″ distance from the eye, so long as any power of accommodation remains, the near point cannot be removed so far as a distance of 8″ from the eye; and even when all accommodatory power disappears or is lost, whether naturally or by atropia paralysis, the near and distant point of distinct vision will merely coincide at a distance of 8 inches from the eye. Still less can a person whose myopia is higher than ⅛th, or 5 D, become presbyopic.

If the myopia be moderate in amount, then, as age advances, the near point may recede beyond 8″; and in such a case the myopia will require to be corrected by concave lenses to enable the person to see distant objects clearly, while at the same time the presbyopia will have to be corrected by convex lenses to make up for the deficiency of accommodation for seeing small objects at near distances.

Presbyopia with Hypermetropia.—As in the hypermetropic eye the distant point of distinct vision is negative, and infinite rays require a certain amount of convergence to be imparted to them, in order that they may be brought to a focus on the retina, the Ac. is trenched upon for affording this required convergence. The H. is thus not immediately apparent; it is covered by the Ac. which it borrows, as it were, from use for near objects in order to obtain clear vision of distant objects. The H. thus becomes concealed or is *latent.* If the H. is very moderate in amount, and the subject is young so that Ac. is in abundance, the existence of H. may readily be overlooked. The amount of Ac. which is borrowed for the service of the H. in supplying the refractive deficiency has, under such circumstances, very little effect on the position of the near point in respect to change of its actual distance, and this change may readily, therefore, escape notice. If a young person who is emmetropic can exert Ac. equivalent to a convex lens of 12 D, the near point of distinct vision will be 3⅓ inches from the eye; if the Ac. be lessened by 1 D the near point will only recede to about 3⅔ inches; and if lessened by 2 D to 4 inches, differences which would be too slight to be noticed. If the Ac. were completely removed, as by atropia paralysis of the ciliary muscle, the H. would be readily detected, for a suitable convex lens would improve distant vision. But without this being done, the H. may be unnoticed until an advanced period of life.

If, however, the H. be considerable in amount, the early recedence of the near point of distinct vision, or early occurrence of Pr., will sufficiently prove its existence. As the distant point of distinct vision in the hypermetrope is, as it were, further from the eye than it is in the emmetropic eye, while the power of accommodation is the same at the same ages in both, it follows that, under all ordinary conditions, the near point of distinct vision will be further removed from the hypermetropic eye than it is from the emmetropic eye at corresponding ages of life. If the H. be excessive, the near point will be beyond 8″ very much sooner in the hypermetropic person than in the emmetropic person, and Pr. will occur proportionally earlier in life in such a hypermetrope than it does in the emmetrope. This rapid occurrence of Pr. at once proves its association with H. When presbyopia is under these circumstances fully established the hypermetropia will require to be corrected by a suitable convex lens to secure clear vision of distant objects, while the presbyopia will have to be corrected by a lens of still greater converging power—one that will not only correct the general deficiency of refractive power of the eye, or the hypermetropia, but that will also make up for the loss of accommodatory power so as to enable the eye to deal without inconvenience with small objects at a near distance from the eye.

CHAPTER V.

On Impaired Vision Due to Strabismus and on Defects of Colour-sense.—Strabismus.—Definition.—Forms of Strabismus.—Directions of Deviation.—Apparent Strabismus.—Images in Convergent and Divergent Strabismus.—Concomitant Strabismus.—Diplopia.—Diagnosis of Concomitant and Paralytic Strabismus.—Measurement of Deviation in Strabismus.—Treatment.—Influence of Strabismus as to Military Service.—Colour-blindness.—Definition.—Symptoms.—Varieties.—Causes of Colour-blindness.—Acuteness of Colour-sense.—Diagnosis.—Holmgren's Test.—Proofs of Kind and Extent of Colour-blindness.—Thomson's Application of Holmgren's Test.—Maréchal's Lantern-test.—Colour-sight in the Royal Navy.—Board of Trade Regulations.—Amblyopic Colour-blindness.—Influence of Colour-blindness in the Military Services.

On Impaired Vision due to Strabismus and on Defects of Colour-sense.—It will be advantageous to describe in this chapter two defective ocular conditions, each of which exerts a special influence on quality of vision, viz., strabismus and achromotopsia. The former, if it exist to such an extent as to impair the power of sight necessary for the duties of a soldier, is at once seen in the ordinary examination of a recruit, but gives rise to subjects of special consideration when it occurs in enlisted men in the ranks; while the latter, though of less general importance in the army than it is in the navy, gives rise to grave difficulties in respect to some particular duties which soldiers may be called upon to discharge in military service.

STRABISMUS.

Definition.—Squint. Abnormal obliquity of the optic axis in one or both eyes. Malposition of the two eyes relatively to each other of such a kind that the directions of their optic axes are not in mutual accord. The visual lines do not meet together at the distance at which a given object is looked at, and true binocular vision is consequently unattainable by persons affected with strabismus.

Various Forms of Strabismus.—Two distinct forms of strabismus, due to different causes, are met with; one functional, depending directly upon irregular muscular action, originating in, or accompanying, anomalous states of refraction, or impaired vision of one or both eyes, and generally distinguished by the name of "concomitant strabismus," from the squinting eye accompanying the normal eye in all its movements; the other pathological, produced by partial or complete paralysis of one or more external muscles of the eyeball, or due to pressure from causes existing within the orbit. In the first of these two kinds of strabismus all the muscles act, but the normal concert of action is not maintained in binocular vision; in the second, the movements of one or more of the muscles are impeded, or entirely arrested. The term "strabismus" is employed by many persons to designate only the former kind, or true concomitant strabismus; absence of concordance in the visual axes from defective innervation or complete paralysis being classed under other headings, such as paralysis of the special ocular muscle or muscles affected, or diplopia.

Direction of Deviation in Strabismus.—Strabismus is commonly either *convergent*, the squinting eye being turned toward the median line; or *divergent*, being turned outwards. The deviation may, however, be upwards or downwards, though it is rarely so. In convergent and divergent strabismus, the retinal images of an object are separated laterally, but remain in the same horizontal plane; in the other directions of deviation, they vary in altitude and inclination according as the superior and inferior recti or oblique muscles are involved.

When the subject of convergent strabismus looks at an object one eye only is visually directed upon it, the other eye has its visual line directed inwards; in the same way, when the subject of divergent strabismus looks at an object, one eye only is directed toward it, but the other eye has its visual line directed outwards. In either case, while the sight is thus fixed upon the object, the deviation is limited to the eye which is turned inwards or outwards.

The deviation may only occur at intervals, or after occasions of long-continued employment of the eyes at near objects, and under conditions of unusual ocular strain and fatigue, or general weakness; but although the occurrence of the deviation, or of the strabismus, may thus vary, the direction in which the deviation takes place, when it does occur, will always be alike in the same eye.

Apparent Strabismus.—A condition which simulates strabismus is sometimes noticeable, and is usually referred to under the name of *apparent strabismus.* It depends upon the angle formed by the meeting of the visual line with the line of the optic axis at their point of intersection within the eye. (See Visual Axis, p. 3.) The relative positions of the two eyes, as elsewhere mentioned, are judged of by observing the relative positions of the centres of the two corneæ with respect to each other and to the middle of the palpebral opening. When two emmetropic eyes are regarding a distant object, the visual lines of the eyes are practically parallel, and, as these lines pass a little internal to the centres of the corneæ, it follows that the centres of the corneæ must be turned a little outwards in respect to the middle of the palpebral apertures. In emmetropic eyes this divergence or apparent strabismus, is so slight as to be hardly observable even on close inspection. The divergence is, however, increased in hypermetropic eyes, as the angle formed by the meeting of the optic axis and visual line is greater, and the apparent strabismus becomes all the more marked. In myopic eyes this angle is lessened, and the visual line may even change position and pass outside of the optic axis, when the appearance of strabismus may be presented, but with a convergent instead of a divergent direction.

Images of Objects in Convergent and Divergent Strabismus.—In *convergent* strabismus the two images of an object are formed on the corresponding retinæ; that which appears on the right side belongs to the right retina; that on the left side belongs to the left retina. In *divergent* strabismus the images are crossed and formed on the opposite retinæ; that which appears on the right side belongs to the left retina, that on the left side to the right retina. The relative positions of the images of an object in some instances of diplopia depending on slight degrees of muscular inefficiency, in which the deviation is so limited as to be hardly noticeable by ordinary observation, are almost the only means by which a surgeon is enabled to decide what particular muscle or muscles are affected. Their respective situations in relation to the two eyes will be rendered obvious to the patient at once if the two images are seen by him under different colours, as may be effected by causing the patient to look with one eye through stained glass. If the deviation be horizontal, and the images are homonymous, there is convergent displacement, and the external rectus muscle is affected; if crossed, there is divergent displacement, and the internal rectus muscle is affected.

The frequent associations of convergent strabismus with hypermetropia, and of divergent strabismus with myopia, have been already remarked on in the sections on these refractive conditions.

Concomitant Strabismus.—Concomitant strabismus may be only occasional, or it may be persistent. The deviation may alternate between the two eyes, each in turn being capable of directing its visual line on the object while the other deviates; or one, or both eyes, may be permanently displaced. When the deviation alternates between the two eyes, the amount of deviation in the right eye when the visual line of the left eye is directed upon the object looked at will be equal to that of the deviation in the left eye, when the macula lutea of the right eye is in line with the object.

In the strabismus of muscular paralysis the loss of power of the eye to move in the line of impaired, or lost, action of the paralysed muscles and the deviation in the opposite direction are constant.

When the strabismus exists only to a moderate amount, and the diviation is limited to one eye, it is sometimes not easy of detection so long as the two eyes are observed together. But it may usually be readily demonstrated, if the retinal functions of the two eyes are preserved, in the following way. The person under observation is directed to regard an object at the distance of a few feet in front of him. Each eye is then alternately covered by the hand of the observer. When the eye whose visual line is directed to the object is covered, the squinting eye may be noticed at once to change its position. It will assume a direction which will bring it visually in line with the object; and equally, on again uncovering the other eye, it will recede from the new to its former place.

Diplopia.—Whenever the physiological harmony of the visual lines is interfered with in binocular vision, as happens with strabismus, the discord necessary causes the formation of double retinal images, but does not necessarily cause diplopia, or double vision.

Diplopia does not exist in the large majority of cases of concomitant strabismus, but is constantly found in strabismus due to paralysis, or partial inefficiency of one or more of the ocular muscles.

There are several reasons why the subject of concomitant strabismus can avoid taking note of the image in the displaced eye, while the subject of paralytic strabismus is unable to do so. In the former, the eye whose visual line is properly directed on the object has its image formed on the macula lutea, and it is of course relatively sharp and distinct; while the image in the displaced eye is pictured on a part of the retina away from the macula lutea, and is, therefore, more or less confused and indistinct. The relative displacement of the two eyes, or the strabismal angle, remains constant, for in concomitant strabismus there is no interference with the range of the muscular movements of the globe of the eye, as in paralytic strabismus, but only with the *position* of the range over which the movements take place. In consequence, the indistinct image on the retina of the displaced eye is always formed in a fixed part of the retina; just as much so as the sharp image is formed on the macula lutea of the normally directed eye. The power and habit of ignoring it are thus more readily acquired by the subject of concomitant strabismus in the efforts which he instinctively makes to rid himself of the troubles of double vision. The retinal sensitiveness of the part where the imperfect or spectral image occurs becomes lessened from disuse, and the suppression of mental attention to the image becomes still more easily and fully established. On the other hand, in strabismus due to paralysis of one or more muscles, the relative positions of the two retinæ are constantly changing as objects in different positions are looked at, and corresponding changes constantly occur in the situations of the retinal images. If, for example, the external rectus of one eye be paralysed, causing a certain amount of inward deviation of this eye, as the sound eye turns inwards, or in a direction toward the paralysed muscle of the deviated eye, the strabismus is rendered more and more obvious—the strabismal angle becomes greater, and the distance of separation of the double images in the two eyes is increased. In the opposite direction the two eyes in the case supposed will act more in concert as the internal straight muscles have not lost their integrity, and at a certain point the visual lines may even both centre in the object, and the diplopia disappear. The strabismus is thus seen not to be constant, as it is in concomitant strabismus, but varies according to the position of the object looked at, and consequently the position of the image in the displaced eye is equally shifting and inconstant. There is little to interfere with the retina retaining its normal sensitiveness over its whole area, and under these circumstances the strabismal subject finds himself unable to suppress perception of the second image when it occurs.

When concomitant strabismus occurs in very early life, the suppression of the images in the squinting eye seems to take place with the utmost facility, amblyopia is established, and if the strabismus be not rectified, the retinal sensitiveness becomes lost beyond recovery.

Diplopia, due to slight muscular paralysis, may be noticed by a patient before strabismus is visible to an observer. The amount of diplopia may vary from haziness due to overlapping of the two images at varying distances, and may be evidenced by the difficulty of co-ordinating the touch with the sight of objects as well as by the vertigo and other subjective symptoms to which diplopia usually leads. If two separate images are noticed, the sharper image produced on the macula lutea of the sound eye, and the weaker image on the retina of the deviated eye, may be distinguished by the aid of the colour test elsewhere mentioned, if they are not otherwise recognisable; and the recognition as soon as established will indicate not only which eye is disordered, but also the affected muscle or muscles. If two images of a bright object, as of a lighted candle, placed at a distance are seen, and one image is coloured by the intervention of coloured glass before one of the patient's eyes, the patient will readily point out to the observer the situation of the image belonging to the eye before which the coloured screen is placed and that belonging to the other eye. The observer will at once see from the relative positions of the two images, in which of the patient's eyes the true image is formed. The affected eye is thus made known, and the situation of the displaced image, relatively to that of the true image whether it be to its right or left hand, or above or below, indicates the muscle or muscles which are at fault in this eye. The displaced image always appears on the side opposite to the ocular deviation, so that if the images are homonymous, convergent strabismus is shown to exist, while, if they are crossed, divergent strabismus is indicated. If, for example, it be the muscle concerned in convergence which is affected, say of the right eye, leading to divergent displacement, the spectral image will be crossed to the left hand of the true image as seen by the patient; if it be the muscle of divergence which is affected, leading to convergent displacement, the false image will be to the right side of the true image as seen by the patient and indicated by him to the observer.

Diagnosis of Concomitant and Paralytic Strabismus.—The conditions already mentioned form sufficient means of distinguishing between these two forms of strabismus, but one other difference between them which is useful for purposes of diagnosis, may be mentioned. The characteristics of concomitant strabismus, which have been already referred to, are: 1. The affected eye retains its natural range of movement, but this range is displaced, the movement does not take place in the normal arc, the eye being able to turn more in one direction, and less in the opposite direction, than the normal eye; 2. The deviation of the affected eye, and the amount of disagreement in direction of the visual lines of the two eyes, at whatever distance the object may be placed which is looked at by them, are constant; and 3. The displaced, or spectral image, formed in the affected eye is mentally ignored, so that diplopia does not occur. On the other hand, in paralytic strabismus, 1. The range of movement of the affected eye is always lessened in the direction of the paralysed muscle; 2. The amount of deviation of the affected eye, and of dissociation of the visual lines of the two eyes, are not constant, but vary with the different directions of the objects toward which the patient turns his eyes; and 3. Diplopia always exists in the range of action of the paralysed muscle, in all cases in which the retinæ retain their sensibility.

There is another symptom by which the paralytic strabismus may be distinguished from concomitant strabismus. If, while the head remains fixed in position, the healthy eye be covered by a diaphragm of frosted glass, at a time when the patient is looking toward an object, the affected eye will make a slight move, in order to try and adjust its visual line upon the object. This movement of the affected eye may be seen to be accompanied by a movement of the healthy covered eye, so that if the other is directed on the object, the covered eye becomes the squinting eye. In paralytic strabismus, this movement of the covered sound eye exceeds in extent the movement of the affected eye, because the slight movement of the affected eye owing to its defective innervation, requires a greater effort of the will to effect it, than it would if the innervation were perfect. This increased effort affects the associated muscle of the sound eye, and so leads to a greater amount of movement through its agency. The deviation of the affected eye is usually described as the *primary* deviation, the movement of the sound eye under the circumstances named, as the *secondary* deviation. On the other hand, in *concomitant strabismus*, under similar circumstances, there is no difference in the extent of movement of the two eyes. When the healthy eye is covered, whatever may be the distance to which the affected eye moves in order to direct its visual line upon the object, the extent of the associated movement of the covered eye will be precisely the same. The rule is thus deduced that in all cases of paralytic strabismus the *secondary* deviation exceeds the *primary* deviation, while in concomitant strabismus the two deviations are exactly equal.

Measure of Deviation in Strabismus.—The linear measurement of the deviation of a squinting eye may be made in either of the following ways. Let the patient be directed to look at a distant stationary object with both eyes free, and while he is doing so, mark with a dot of ink on the margin of the lower eyelid of the *squinting* eye, the spot which would fall within a vertical line prolonged from the centre of the deviated cornea. Then close the normal eye, and let the affected eye be directed to the object, and, as before, mark a spot on the lower lid corresponding with a vertical line drawn through the centre of the cornea in its new position. The distance measured between the first and second spot gives the linear measure of the deviation. Or, while the two eyes are open, a spot is marked on the margin of the lower lid of the *sound* eye in line with the centre of the cornea. A spot is then marked on the border of the lower lid of the affected eye, which exactly corresponds in position with that of the spot placed opposite to the centre of the cornea of the sound eye. A second spot is then made to mark the situation of the centre of the cornea as it exists in the squinting eye. The distance which separates these two spots indicates the amount of displacement of the optic axis. The distance between the two spots can be measured by an ordinary tape measure, graduated with sufficient fineness, but still more conveniently by means of a strabismometer. (See p. 32.)

Treatment of Strabismus. — Although in comparatively mild cases of paralytic strabismus, such as sometimes result from constitutional states—from syphilitic, rheumatic, or diphtheritic disease, for example—relief may often be effected by suitable remedies; and also in the milder forms of concomitant, or functional, strabismus, by the aid of prisms, in exercising and gradually strengthening the weaker muscles, and so enabling them to overcome the stronger action of their opponents, together with correction of any abnormalities of refraction that may co-exist by appropriate lenses; still, in the majority of cases, especially when the deviation is fully established, it only admits of cure, or palliation, by the operation of tenotomy. The proper treatment of strabismus usually requires very close and accurate observation of each particular case concerned, and a consideration of the subject does not fall within the scope of this manual; a description of the various proceedings involved in it will be found in all systematic works on diseases of the eye and their treatment.

Influence of Strabismus as regards Military Service.—The disfigurement caused by well-marked strabismus, and the uncertainty it gives rise to in others, as to the precise direction in which a man is looking, are sufficient reasons for rejecting a recruit seeking enlistment, but the most important objections are the monocular vision on the one hand, and the amblyopia on the other, with which concomitant squint is usually accompanied. Operative interference may remove the disfigurement, but will not repair the amblyopia if it be of long standing. I have known a candidate for an army commission get the concomitant strabismus with which he had been affected from childhood, rectified by surgical operation, but a year afterwards, the amblyopia of the eye which had been displaced remained without any apparent improvement. Practically the influence of concomitant strabismus on aptitude for military service is settled by the ordinary tests for acuteness of vision. If the soldier can count the test-dots *by each eye* in succession at the required distance, although a slight amount of functional strabismus may be apparent, there is no sufficient cause for rejection: if the test-dots cannot be counted at the regulated distance, whether the impediment may be owing to the refractive condition of the eye, or to amblyopia the result of disuse, the results as regards the unfitness of the candidate for military service in the ranks will be the same. As regards a candidate for an officer's commission there will be this difference; if the difficulty in the way of correcting the test-dots be due to the ametropia only, he may overcome it by wearing suitable glasses; if amblyopia from disuse exist in addition, no glasses will rectify it so as to enable him to pass the required tests.

Paralytic strabismus is a sufficient cause for rejection of a recruit. It is therefore only likely to be met with after a soldier has been serving in the army, and, when once it has occurred, it is usually a cause of the man being discharged from further service, owing to its liability to recur, even though it may appear to be only temporary in its nature. In occasional cases, where it has been traceable to the effects of a slight attack of sunstroke in a tropical climate, it may disappear altogether on removal to a temperate station, but under many other conditions, when induced by morbid states, as syphilis and others, though it may be removed for a time by appropriate treatment, there is no security against the risk of its return. When paralytic strabismus is fully established, the attendant diplopia, and loss of ocular movement in the direction of the paralysed muscle, and with it frequently part of the field of vision, as a matter of course, incapacitate a soldier for further military service.

II. COLOUR-BLINDNESS.

Definition.—Imperfection, or total deficiency, of visual perception of one or more colours. The term *dyschromotopsia* is employed to express dulness of the colour-sense, or a difficulty in distinguishing colours and their various shades and combinations; *achromotopsia*, to express complete absence of perception of one or more colours, or in other words, total inability to distinguish truly one kind of colour from another. Colour-blindness is of two kinds, viz., (*a*.) *congenital colour-blindness*, a defective state of vision, often hereditary, under which the subject, though possessing distinct perceptions of form, and of contrasts of light and shadow, is unable properly to recognise diversity of colour, or even to perceive certain colours; and (*b*.) *amblyopic colour-blindness*, deficiency, perversion, or loss of colour-sense associated with morbid states of the retina, which are mostly manifest to observation.

Symptoms.—Colour-blindness may exist without the subject of it being aware of his defect, until his attention is directed to it by experimental trials, or the occurrence of some special difficulties consequent on his disability. On looking at the colours of the spectrum, some of them may be seen correctly, while others that are really very unlike, produce a similar optical effect, and are only distinguished by appearing to vary in intensity of light and shade.

so long as the signals and lights under observation are put before them under conditions of equal clearness. The colour-blind person has trained himself to observe these qualities as substitutes for his want of colour-sense; just as the totally blind educate and refine their senses of touch and hearing to supplement their loss of visual power. There have been repeated proofs that colour-blind persons can learn to distinguish between differently coloured lights, not by the differences in their respective colours, but by differences in their illuminating power. They do not know the green from the red light because one is green and the other red, but because the amount of light emitted by the one differs from the amount of light emitted by the other. There may also be an acquaintance with some special effects or differences in quality acquired by repeated observation which may help the colour-blind, that persons who possess a naturally normal sense of colour are unable to appreciate. In this way colour-blind persons may pursue their callings for a certain time with impunity, notwithstanding their defects, which, however, may lead to dangerous results at any moment. Many atmospheric conditions and other circumstances may cause the clearness and intensity of light of particular coloured signals or lights to differ, or may make them appear to differ, in these respects, and as these variations in luminous intensity take the place of differences of colour with the colour-blind persons just referred to, it is obvious that no safe reliance can be placed on such substitutes for the true colour-sense. The importance of not placing reliance or any substitutes of the kind is forced on the attention, all the more from reflecting on the very serious nature of the issues which must depend under a variety of circumstances upon the observers concerned in them possessing a full and correct appreciation of the colours exposed to view.

Holmgren's Test.—The test now generally adopted, or some modification of it, is the one described by Professor Holmgren, of Sweden. Holmgren's test is simple and easily applied. A number of skeins of wool of different colours are collected together. They consist of the colours corresponding with those of the spectrum, viz., red, orange, yellow, green, blue, indigo, and violet, together with yellowish green, greenish blue, purple, rose, brown, and grey. There are several shades of each colour, and at least five gradations of tint, or degrees of saturation, of each shade of colour, from the deepest to the lightest. The skeins of wool are mixed together in a heap on a table, in full daylight, not by artificial light, and the examiner takes from it one of the skeins, and places it at some little distance from the general heap. The person under examination is then requested to pick out the other skeins which most resemble the test skein in colour, and to place them side by side with it on the table. A succession of similar tests may be applied in the same manner. Either very light or very deep shades of colour are recommended for the test objects. The person under examination is not required to *name* the colours. His chromatic perception is judged by the manner in which he responds to the test. If faulty colour-sense be exhibited in the performance of the task, the tests must be continued in order to determine the kind and extent of colour-blindness, whether it be simply defective perception, or total absence of perception, of either red, green, or violet, or of any two of these colours.

To ascertain the Kind and Extent of Colour-blindness.—The following mode and order of proceeding to establish the diagnosis is prescribed by Holmgren :—

1st Proof. A skin of pure light-green wool is given as the test. The specimen should neither be "blue-green" or "yellow-green." On examining the skeins which have been selected as similar in colour and shade, if they have been selected readily and found to be all of green tints, chromatic perception is "not faulty," if after hesitation and difficulty in selection, there is an approach to confusion of colour, the "colour-sense is weak ;" if complete confusion of colour, if the green is matched with grey, brown, or even with red, the conclusion is that there is "colour-blindness."

2nd Proof. A skein of purple colour, that is, a mixture of red and blue, is now given as the test. If all or the greater part of the skeins selected as being of the same shade are found to be so, the colour perception is "not faulty ;" if only blue and violet wools have been selected and joined to the purple test-skein, in other words, if the person tested sees the purple only as blue, there is complete *colour-blindness for red;* if green or grey, or both, have been selected as specimens of the same colour and shade as the purple, the person under examination is "completely blind for green ;" if he join red and orange skeins to the purple wool, he is "blind for blue and violet." If wool of all colours, of the same shade or degree of saturation, should be taken as being alike in colour, there is evidence of complete and "total colour-blindness."

The proofs above given Holmgren regards as sufficient for all ordinary cases, but for special individuals, as for official persons on whose right perceptions of colours important issues depend, he regards it advantageous to take further proof in confirmation of the conclusion arrived at from the foregoing tests, and then uses a skein of pure red wool as the test-object. The colour-blind show by their selection that they confound green and red together, the "red blind" persons particularly selecting, in addition to red, shades darker than the test-skein, such as shades of deep green, olive, and dark brown ; "green blind" persons shades lighter than the red.

Thomson's Application of Holmgren's Test.—Dr. Thomson, of Philadelphia, has devised an instrument based on Holmgren's plan of testing colour-blindness which can be used by any intelligent observer for noting and recording whether a person is colour-blind or not ; the ophthalmic surgeon being only referred to in cases which appear doubtful, or for confirming the observations when colour-blindness is stated to exist. This is reported to have been largely used in testing the colour vision of railway employés, with the result of discovering about 4 per cent. to be colour-blind. In this instrument 40 skeins of coloured wool are employed, the tints selected being those of the three test colours, green, purple, and red, together with the usual "colours of confusion." The skeins have each a small metal plate attached bearing a particular number, which can be quickly read off and noted by the examiner. One half, or 20 skeins, are devoted to the green test, the 10 odd numbers being shades of green, the 10 even numbers "confusion colours," as greys, light browns, and others; the skeins from 21 to 30 have purple tints on the odd numbers, and blue tints on the even numbers; the skeins from 31 to 40 have red tints on the odd numbers, and brown, sages, or dark olives on the even numbers. The numbers are concealed from view of the person under examination, who merely selects the tints which seem to him to correspond to the test-tint given to him, on the same principles as have already been explained; while the examiner to whom the numbers are accessible simply notes on a proper form the numbers of the skeins, whether odd or even numbers, which have been selected. Reports thus obtained, and subsequently subjected to professional scrutiny in the cases of those who have appeared to be colour-blind, have led to the proportion of 4 per cent. already mentioned.

Maréchal's Lantern Test.—A convenient method of examining for colour-blindness has been adopted in the naval schools of France on the suggestion of Dr. Maréchal, Principal Fleet Surgeon. It is a test by artificial light, and the manner of applying it is similar to that followed in the trials by Holmgren's wools. A lantern is arranged in such a way that a variety of colours may be shown by the same light on shifting the glasses. The examiner and the person under examination each have a lantern, and on the former showing a particular light, the latter has to show a light of the same kind. Holmgren's wools are also used as tests by daylight, and the same mode of examination is carried out in the cases of all pilots and signalmen in the French navy. Coloured signal lights, in addition to tests by daylight, are employed in various countries in the examination of officers and men of the State navies as well as of others belonging to the mercantile marine.

Plan for Testing Colour-sight in the Royal Navy.—All naval officers (medical officers only excepted) and sailors now enter the Royal Navy as boys, and, I am informed, they are invariably tested as to their perception of colour, and that any notable deficiency in power of perception is regarded as a sufficient ground for rejection. The following is the order given in the "Queen's Regulations and Admiralty Instructions," regarding the examination in respect to colour-sight, of candidates for admission in the Naval Service or into the Royal Marines. "Whenever test-types are supplied, the power of vision of each eye separately, as well as together, is to be ascertained. If the persons under examination fail to distinguish the colours" (of the coloured test-types), "they should be tried with brighter and decided colours; for this purpose red, blue, green, and yellow ribbon flags may be used." Coloured wools are in use at the Admiralty for doubtful cases among officers.

Influence of Colour-blindness in the Military Services.—This affection, which is very important as regards those who have to depend on coloured signs for guidance as signal officers, look-out men at sea, and railway officials; chemists, and others concerned in practical analysis, in which the presence of particular ingredients is determined by such tests as coloured solutions, or by effects produced so far as colour is concerned; as regards physicians in the diagnosis of certain diseases characterised by colour, as *scarlatina;* and even as regards officers in general command who require to be able to recognise clearly and quickly the colours of uniforms;* has not been regarded as a disability in officers of the army or soldiers in the ranks. There are no orders for the colour-sense of men brought as recruits or of candidates for commissions in the army, to be tested by examination. Neither has it been included in the lists of disorders of the eyes incapacitating men for military service either in our own or, I believe, in any foreign armies. It is important, however, for medical officers to be acquainted with the nature of colour-blindness, and with the methods of diagnosing its several varieties, as they may be required to decide whether the defect exists or not in special cases submitted to their judgment. The serious nature of the defect is acknowledged as regards officers and sailors of the Royal Navy who have to distinguish readily and accurately signals at sea, for the power to execute this duty aright depends more upon correct appreciation of the colours than of the forms or even the markings of the objects presented to view. A colour-blind officer or sailor could not recognise the distinguishing pennants of ships nor distinguish signals conveyed by them, for they have all the same shapes and dimensions and only differ in their colours. This remark equally applies to most of the flags in use for signalling, as well as to the coloured lights, red, green, or white, which are shown by vessels at night to indicate their position and the direction which other vessels are to take in steering past them. The ill-consequences of colour-blindness in such cases may not be confined to mere failure of recognition of the objects concerned, but in many instances an erroneous interpretation of them induced by the defect may lead to most grave and irremediable evils. It is not to be forgotten, moreover, that congenital colour-blindness is an incurable disorder, and that while the use of the telescope may make up for some visual defects, it cannot lessen or in any degree correct the defect of achromatopsia. Candidates, therefore, for service in the Royal Navy, both officers and men, require to be carefully examined in respect to their faculty of distinguishing colours. The colours employed for pennants and flags in the Royal Navy of Great Britain are the three colours, red, blue, and yellow, which were formerly regarded as the three primary colours of the spectrum, together with white and black, while at night, red, green, and white lights are used, so that it is for these colours that candidates chiefly require to be tested. At the same time it is not to be forgotten that, in addition to the simple colours named, compound colours are used in the flags of foreign navies.

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* I was once aware of an officer discharging the duties of a musketry instructor who could not distinguish the red flag or "danger signal" at target practice by its colour, but only by its larger relative size; and of a general officer who was necessitated from the same defect to ask a member of his staff whether a body of troops were dressed in red or blue. I have also known a surgeon in civil-practice who was temporarily affected with achromotopsia, during which period he could not distinguish red colours. A patient affected with scarlatina appeared to him to be of a yellowish tinge, as if he were suffering from jaundice. Professor de Chaumont informs me that difficulties have arisen in some instances among the surgeons on probation in the execution of practical analysis in the Hygienic Laboratory of the Army Medical School from the fact of the persons concerned being colour-blind; and Professor Aitken equally in the Pathological Department on occasions when the nature of specimens seen under the microscope has had to be determined by the colours resulting from the application of certain reagents.

Amblyopic Colour-blindness.—This is characterised in some cases by imperfect perception, or loss of perception, of certain colours, the results of morbid conditions of the retina and optic nerve. Abnormal sensations of colour, such as the prevalence visually of a tint of some particular colour independent of whatever may be the actual colours of the objects presented to view, should be distinguished as "coloured vision" rather than as "colour-blindness." Red, in amblyopic, as in congenital achromatopsia, is the colour which is most frequently not discerned, while the power of distinguishing yellow or blue remains the most persistent. Amblyopia with central scotoma seems to be particularly liable to be attended with impairment of perception of colour. Optic neuritis, neuro-retinitis, and any diseases inducing atrophic changes in the optic nerve have the same tendency, and an alteration in the right perception of colours sometimes appears very early in their course. The disabling influence of this form of colour-blindness as regards military service depends on the amblyopia and morbid states with which it is associated rather than on the colour-blindness or colour-perversion itself.

CHAPTER VI.

Acuteness of Vision.—Normal Acuteness of Vision.—Alertness of Vision.—Relative Acuteness of Vision.—Measurement.—Optometric Test Objects.—Hair-wire Optometer.—Jäger's Test Types.—Snellen's Test Types.—Burchardt's Sight Tests.—Snellen's Test Types in Military Practice. — Amblyopia. — Definition, Causes, Symptoms, and Diagnosis of Amblyopia.—Hemeralopia.—Nyctalopia.—Hemiopia.—Scotoma.—Asthenopia.—Definition, Causes, Symptoms, and Diagnosis of Asthenopia.—Dimsightedness, from interference with the passage of light through the Eye.

ACUTENESS OF VISION.

THE term "Acuteness of Vision" has reference to quality of retinal perception, and might strictly be limited to the functional capacity appertaining to the percipient retinal elements; but as this capacity can only be practically tried or expressed by a measure of that on which the retinal function is exercised, the term, as usually employed, is applied to the size of the retinal image which can be ocularly recognized, or, what amounts to the same thing, the size of the object which, under favourable conditions, can be seen by the eye at a certain determinate distance.

Normal Acuteness of Vision.—Normal acuteness of vision is generally understood to imply clear recognition in full daylight of an object toward which the eye is directed under the smallest visual angle for which the eye in a state of health is organised. The term normal acuteness of vision only refers to that degree of perfection of which we have experience as regards the human eye; for it seems beyond doubt that some animals, such as certain birds, can see from distances beyond those at which the animals themselves can be seen by the eye of man, and it is quite conceivable that a higher degree of visual acuteness than any hitherto observed might be attained in the human eye through further development of its visual organisation. This implies acuteness of vision at the region of the macula lutea. Complete acuteness of V. can only exist when the organic textures and transparency of the media of the eye are perfect; when its refractive power is accurately adapted to the distance at which the object looked at is placed; and when the retinal sensitiveness, or the functional energy of the visual nerve elements, and nerve conduction are also perfect. An eye may be emmetropic, yet its visual acuteness defective at all distances, owing to cloudiness of some of the media, to defective or disordered condition of certain retinal elements, or other morbid conditions; on the other hand, an eye may be ametropic, and possess perfect acuteness of V. at some distances though not at others, or at all distances when the ametropia is corrected.

From the foregoing it is evident that acuteness of vision may vary in degree from normal acuteness to mere recognition of light of a certain amount—quantitative vision. The particular degree of acuteness of V. in any given case will admit of measurement if a definite objective standard of normal acuteness of V. be agreed upon.

Alertness of Vision.—The speed with which particular objects are distinguished varies in different individuals whose degree of acuteness of vision may be found to be similar by ordinary observation. Such relatively slow or quick sight is best defined by the expression of "alertness of vision." Increased alertness of vision accompanies increased intensity of visual impression, as in binocular compared with monocular vision, but appears also to depend on individual habits, and constitutional peculiarities, visual practice, and perhaps also on relative perfection as regards transparency of the ocular media, and, consequently, relative speed in the formation of the retinal images of objects. As senile changes take place in the refractive media and ocular tunics, alertness of vision diminishes, and hence probably in some degree are due the cautious and relatively slow movements of the old. Measure of alertness of

In practice it is found that the hair-wire optometer answers well for intelligent and observant persons, but frequently gives rise to difficulties when men in the military ranks are subjected to trial with it. It is by no means easy to get some persons to decide when perfect definition of the wires is obtained and when the definition first becomes imperfect. Letters that we know must form defined images when they are easily read, and of which we know the images are not defined when they cannot be read, or are imperfectly defined when they can only be read with difficulty, constitute more simple and reliable tests for such persons.

The printed test-types in common use are of two kinds, Jäger's test-types and Snellen's test-types.

Jaeger's Test-types.—These consist of paragraphs printed in the differently sized types which are in ordinary use in printing in different countries. The sentences selected are numbered according to the sizes of their types, the sentence in smallest type being distinguished as No. 1. The numbers increase as the sizes increase. They were at first arranged with a view to overcome the difficulty experienced by ophthalmic surgeons of different countries in understanding the nature of the letters referred to by one another as objects which patients were able to read under special circumstances, whether under different refractive states, after operative proceedings or other treatment, owing to letters being only then distinguishable by technical names arbitrarily adopted among printers and differing in different countries. To get rid of this difficulty Professor Jäger, of Vienna, arranged the types used in different languages according to their corresponding sizes, and distinguished them by numbers as above mentioned. Jäger's test-types in consequence received the names of *types of universal reference.*

The individual letters are not framed on any common principle. Although there is a general correspondence of size in the type according to the number assigned to it, particular letters differ in their dimensions from each other. Some letters differ from others in width or height, and some strokes differ in thickness, whatever the number of the type. Various other differences exist among the letters. The application of these types as accurate tests of acuteness of vision is in consequence necessarily imperfect and limited. They are, however, occasionally useful from their forms being familiar to readers, so that their recognition is not interfered with as far as any peculiarity of shape is concerned. But such letters would manifestly be more generally serviceable if they were fashioned on such a fixed basis that every one of them when placed at a given distance presented the same visual angle, and had definite relations in respect to size with all the other types. Snellen's types were designed for the purpose of meeting these requirements.

Snellen's Test-types.—As Snellen's test-types form the standard by which visual acuteness is tested by medical officers in the English army, and as they are also used in the Royal Navy, for testing vision, their nature and peculiarities ought to be well understood.

Unlike Jäger's test-types, they consist of specially formed letters, all fashioned on one and the same fixed basis. The sets of types are of different sizes, and each set is accompanied by a special number. These numbers bear definite proportions to each other, just as the individual letters of each set of types do to each other.

When he arranged these types Dr. Snellen experimentally determined the smallest visual angle under which letters could be read provided the vision of the reader were of normal acuteness, or, in other words, the least magnitude of the retinal image of a letter which enables that letter to be distinctly perceived, for on the size of the visual angle, as elsewhere explained, depends the size of the retinal image.

Dr. Snellen has taken as his standard that an emmetropic eye of normal visual acuteness, can perceive a plain rectangular object in fair daylight when it subtends a visual angle of the 60th of a degree, or one minute. This is the smallest object that can be seen—the *minimum visible*—according to Snellen's standard. The space such an object would occupy in a circle of 24 inches in diameter, of which the eye may be supposed to be the centre, would be about the 285th part of an inch of its circumference. At a distance of 12 inches therefore, on this basis, the eye can perceive the presence of a plain object about 285th of an inch in size.

But though an uniform object can be seen by the eye when occupying only a space of the 60th of a degree, a complex object, though visible, cannot be recognised under so small a visual angle. The smallest visual angle permitting clear recognition of such broken and irregularly formed objects as printed letters, according to Dr. Snellen's standard, is one-twelfth of a degree, or five minutes. Thus at a distance of 12 inches, the eye can recognise a letter about the 57th of an inch in size, or, according to Snellen, a letter 0·209‴, or 0·0174″, or $\frac{1}{57·47}$th of an inch, in dimensions, Paris measure.*

It is on these principles that Dr. Snellen has arranged his test-types. They are all quadratic in shape, or occupy a space the linear boundaries of which form a square, and are each formed of strokes, or *limbs* as they are called, the breadth of which respectively is one-fifth of the linear dimensions of the square within which the whole letter is contained. They bear numbers from I to CC according to their sizes; No. I being the smallest, No. CC the largest among them. These numbers also express the number of feet at which the types can be read by an eye possessing normal acuteness of vision. When the letters are read at the fixed distances in feet, which are numbered above them, the eye, in seeing a limb of the letter, is seeing an object which occupies an angle of one minute, while in seeing the whole letter it is seeing an object which occupies an angle of five minutes in the visual field.

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* Dr. Snellen has taken 0·209‴, French measure, or 0·0174″, for the dimensions of each of his letters and of the spaces between them, which are to be recognised at a distance of 12″ by a normal eye. At the distance named, viz., 12″ from the cornea, or 12·28″ from the nodal point of the eye, such an object subtends a visual angle of about 5 minutes. The dimensions of the retinal image of an object of this size would be 0·00089″, or $\frac{1}{1123}$″; but if for a letter having a visual angle of 5 minutes a plain object, such as a test-dot, with a visual angle of only 1 minute (0·00348″) be substituted, the dimensions of the retinal image would be 0·000178″, or $\frac{1}{5618}$, and this would approach the size which physiologists have assigned to one of the retinal elements, or cones, at the site of the macula lutea. As many persons are able to see objects under smaller visual angles than that adopted by Dr. Snellen, it is evident that the approximation to the size of one of the retinal elements referred to, variously given from about $\frac{1}{7000}$″ to $\frac{1}{8000}$″, would be more closely attained.

Dr. Snellen has supplied sentences in various languages printed on the same principles as the separate letters, and like them bearing numbers in accordance with their sizes, but it must not be forgotten that when printed sentences are used as tests, some words may be read although the separate letters are not seen distinctly, from the fact of the eyes having become familiar with their general aspect, owing to their frequent occurrence in printed books. Wrong inferences might be drawn from this fact. Separate letters of definite size are not open to this objection; all the parts or limbs of each letter and figure must be imaged with a fair average of distinctness, or the object could not be recognised. Moreover the intervals between the separate letters, numbers, and test-objects, can be arranged to be equal in dimensions with those of the objects themselves, whereas no such systematic plan can be carried out when the letters are grouped in words and sentences.

Arithmetical numbers of various sizes are included among the test-types for persons who cannot read letters but can decipher such figures; and for those who cannot distinguish either letters or numbers, simple objects such as circles, lines, crosses, squares, and others are added. They are drawn on the same principles as the letters, and are intended to be used in the same way.

It will be observed from the foregoing description that Snellen's types have not been designed for giving qualitative estimates of vision, although they may be partly applied as elsewhere explained to such a purpose, but have been solely arranged as means of obtaining quantitative estimates of visual power.

Snellen's Types on the Metrical Scale.—The test-types for the determination of the acuteness of vision which have been in general use in the British service were officially distributed to the army medical officers in the year 1864, shortly after that edition was published. In an edition published in 1882, Dr. Snellen adopted the metre as the standard of unity, and since that date all his test-types, or optotypes, and other optometric objects, have been numbered on the metrical system. They bear figures above them which indicate the numbers of metres, or parts of metres, at which the test-types should be read by an eye possessing average normal acuteness of vision, in the same way as the former test-types were marked in Paris feet and inches. There is no change in the formula for expressing the acuteness of vision:—it is still $V. = \frac{d}{D}$. The distances for which the types are arranged vary from the smallest, in which D is equal to 0·5 m., to the largest, with which D is equal to 60 m. The smallest type should therefore be read at a distance of about 20 English inches, the largest at 200 feet, by an eye endowed with normal acuteness of vision. In these later editions, some improvements have been made in the tables for detecting astigmatism, and in the tests for acuteness of colour-sight. The edition of 1864, in which the types are numbered in feet and inches, still remains the edition in use in the British service.

Burchardt's International Sight-tests. — These test objects, designed for enabling military surgeons and others to determine the acuteness of vision, have been formed on principles which differ in some respects from those of the preceding optometric objects. They are intended to enable surgeons to ascertain the near and distant points of distinct vision, together with the existence of astigmatism without the aid of lenses. They were first published in 1870, but a larger third edition was published in 1883.[*] The purpose of Dr. Burchardt was to get rid of the objections to the use of letters—viz., that they are only applicable to men who know how to read, that some letters are easier to be recognised than others, that this recognition involves mental effort as well as the act of seeing, and that the upright strokes of the taller letters are often not distinguishable at the same distances as the cross strokes of the shorter letters owing to astigmatism. The test objects for acuteness of vision employed by Dr. Burchardt are black discs of different sizes on a white ground. I had already called attention to the use of discs for the same purpose in the Army Medical Reports for the year 1860.[†] My arrangement of the sets of discs was such that they corresponded in their diameters with the series of Jäger's test types; but they were very badly printed, and were needlessly scattered by the printers, in a manner never intended, over the pages of the paper which they were designed to illustrate. Dr. Burchardt has greatly improved on the discs just referred to, and has grouped them together on different principles. Instead of measuring the acuteness of sight by the visual angle under which the separate objects are recognised, Dr. Burchardt measures it chiefly by the visual angles of the intervals between the objects. Just as the sensibility of the skin, or sense of touch, may be measured by the limit of the distance at which the two points of a pair of compasses are separately felt, so, on Dr. Burchardt's system, the sensibility of the retina, or visual acuteness, is measured by measuring the limit of distance between two objects, or rather their retinal images, necessary for their separate perception. It is therefore the minimum interval of separation of objects appreciable by the retina that constitutes the test of acuteness of vision in Dr.

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[*] "Internationale Sehproben zur Bestimmung der Sehschärfe und Sehweite." Herausgegeben von Dr. M. Burchardt, Oberstabsarzt 1 Kl. &c. Dritte verbesserte und vermehrte Auflage. Kassel. 1883. (International Sight-tests for determining acuteness and range of vision). By Oberstabsaszt 1 Cl. Dr. M. Burchardt. Third improved and enlarged edition. Kassel. 1883.)

[†] Notes on the Examination of the Visual Fitness for Recruits for Military Service, with special reference to instruction in the use of the rifle. "Army Medical Reports," vol. 2 for 1860. London, 1862, p. 462.

Burchardt's international sight-tests. Thus, for example, Dr. Burchardt shows that discs of 0·1 mm. diameter, placed in a row at intervals of 0·1 mm. from each other, and viewed from a distance of 60 cm. (24″) are perceived as a continuous line; at a distance of 20 cm. (8″) appear as a rough line with occasional swellings; at 16 cm., or a little more than 6″, are recognized separately and can be counted. That the power of the eye to see separately, and to count objects of simple forms depends not alone on the visual angle which the objects subtend, but partly on the lengths of the intervals between them, has been shown in a very simple manner with the army test-dots ⅕″ square by Inspector-General Dr. Lawson. When the intervals between them were each of the same dimensions as the test-dots, viz., ⅕″ square, they could be counted by himself at a distance of 36 feet; when the intervals were each ⅖″ square, at 58 feet; when ⅗″ square, at 74 feet; and the same dots with intervals of ⅘″ square between them could be counted at 82 feet distance.

All the sight-tests in Dr. Burchardt's tables have diameters which are 1600 times less in length than the length of the distance at which they are to be seen by an eye of normal acuteness of vision according to his standard. Thus the discs in the 60 metre table have each a diameter of 37·5 mm.; those in the 1600 mm. table, have a diameter of 1·0 mm.; while the discs of the 10 centimetre table have diameters each of $\frac{1}{16}$th of a millimetre. At the distances named each of the discs, and each of the interspaces between every two adjoining discs, subtend a visual angle with the eye of 2·15 minutes. This is 1·15 minutes larger than the visual angle under which the test-dots on Snellen's standard were required to be seen by an eye reputed to possess normal acuteness of vision.

Dr. Burchardt in the last edition of his sight-tests (1883) has adopted the metric system of measurement. The figure of distance attached to his largest discs is 60 metres, and the figures descend to 10 cm., the sizes of the discs decreasing in proportion. He has also added two sheets of block-letters, graduated in size, for distances from 20 metres to half a metre, as well as a sheet of large discs designed for determining at a distance the directions of the faulty meridians in cases of astigmatism. Some of the tables are reduced by photography from accurate drawings, and are clearly engraved on card tablets of pocketbook size, so that they are very portable, while the back of each card bears concise instructions on the manner of using them in the detection of true as well as simulated differences of visual acuteness and refractive power. Special small cards and tables for the diagnosis of astigmatism are added. They are thus conveniently arranged for fulfilling their purpose, but, on the whole, Snellen's test types, although in some respects less scientifically accurate than Burchardt's sight-tests, generally appear to be more serviceable, and as they have been already sanctioned for employment by medical officers in the British army and are now familiar to them, there appears to be no sufficient reason for introducing others into use.

Snellen's Standard of Visual Acuteness.—In practice it will be found that particular eyes, especially sound young eyes, have a considerably higher degree of visual acuteness than the standard taken by Dr. Snellen. An object which subtends an angle of only half a minute, or even one-fifth part of a minute or 12 seconds, when directly illuminated by the sun, is visible to some eyes. Colour has an influence however: a white object with the light of the sun shining upon it may be seen under an angle of 12 seconds, but under the same circumstances, a similar object, but red in colour, would only be seen under an angle about double that size. Sudden change in the intensity of the light to which the eye is subjected, ocular fatigue from prolonged visual efforts, pressure on the globe, and a variety of other causes, will temporarily interfere with the power of reading the types at their normal distances, and, unless taken into account, may lead to an erroneous conclusion in a given case that the visual acuteness is below Snellen's standard, when it really is not so. Some persons can read test-types at distances considerably beyond that indicated by their accompanying numbers; when, therefore, the angle under which they are recognised is much less than an angle of five minutes. I have seen them read, under favourable conditions, at double the indicated distances; when, therefore, the visual angle has been reduced to about $\frac{1}{24}$ of a degree, or $2\frac{1}{2}'$, and V. has been = 2, or twice Dr. Snelleu's standard, and their recognition at a distance of thrice Snellen's standard in a good light is recorded. Snellen's test-types, as numbered, are consequently to be regarded not as standards of perfect acuteness of vision, but of *average* normal acuteness of vision, as deduced from actual observation of a number of persons free from all visual defects; while those in whom V. is found to be twice or thrice Snellen's standards are to be regarded as exceptions to the general standard of normal visual acuteness.

Uses of Snellen's Test-types in Military Practice.—The great value of these test-types is the ease and readiness with which they can be used for practical purposes in ocular examinations. It is not of so much moment whether the standard on which they are based is precisely accurate as to its estimate of normal acuteness of vision, as that the types can be used for at once determining whether the acuteness of V. in any given case is equal to, below, or above their standard. At the same time, Snellen's standard may be accepted as a fair average standard of normal acuteness of V., under the ordinary conditions of everyday life in Europe.

As the letters are all formed on one and the same principle, they are capable of being applied to various uses in the examination of visual acuteness. Being all seen under the same visual angle at the distances indicated, they all at those distances have the same apparent magnitude; and as they are all formed in the same fashion, and occupy proportionate areas, so also at the distances indicated they not only have the same linear magnitude, but also the same apparent superficial magnitudes. Letters of any one size may, therefore, in practice be substituted for letters of any other size, within the limits of distance for which the eye is adjusted, or can adjust itself by the exercise of accommodation, of course provided illumination and other conditions be preserved alike.

Again, if two or more of the types be held at other than the named distances, whether more remote from or nearer to an observer, the visual angles under which they are severally seen will still be alike, so long as the distances at which the different types are placed are relatively in accordance.

Snellen's test-types afford a simple, and practically sufficiently accurate mode of expressing the degree of acuteness of vision. Snellen's formula is the following. If V. (vision) be used to express the acuteness of vision; D the distance at which the type appears under an angle of five minutes, or the distance named with the type used; *d* the utmost distance at which the type can be read by the person under observation then $V. = \frac{d}{D}$. In this arrangement, D is a fixed quantity, *d* a variable one. Examples: The 20-feet types are read at 20 feet, the 30-feet types at 30 feet; then $V. = \frac{20}{20}$ or $\frac{30}{30}$, and the acuteness of vision is normal. If the 20-feet type can only be read when the person approaches the types to a distance of 10 feet, the 30-feet type to one of 15 feet, then $V. = \frac{10}{20}$, or $\frac{15}{30}$, or $\frac{1}{2}$, and the acuteness of vision is only one half of the normal standard. Practically, in determining relative degrees of acuteness of vision by these means, it is better to use one common test-type, the 20′ type, for example, as the standard.

A convenient mode of using Snellen's types is to have the scale of types, one row above the other, placed on a suitable stand in a good light at a fixed distance, a distance, for example, of 15 feet from the person under examination. In the formula $V. = \frac{d}{D}$, *d* then becomes a fixed quantity, and D a variable one. The person whose vision is under trial is desired to read the smallest row of types which he can see clearly at that distance. If he can read the 15-feet type, but none smaller, then $V. = \frac{15}{15} = 1$. If he can read the 12-feet type, then $V. = \frac{15}{12} = 1\frac{1}{4}$, or his visual acuteness is one quarter above Snellen's standard. If he can only at the distance named read the 20-feet type, then $V. = \frac{15}{20} = \frac{3}{4}$, and his acuteness of vision is only three-quarters of Snellen's standard. The advantage of using a distance, such as one of 15 feet, is that there is no need, under ordinary circumstances, for exercise of accommodatory exertion on the part of the person under examination, for the rays of light from objects at this distance reach the eye, practically, as parallel rays, and it is only in the case of hypermetropes, that accommodatory exertion will be employed.

The use of Snellen's types saves time in examining the quality of eyesight in any unknown case. If the person under examination reads with each eye the 20-feet type at 20 feet with ease, there is no ocular defect of sufficient importance to require further investigation. If it, and other types, can only be read short of the normal distances, some defect exists, and the necessity is at once indicated for further examination by trial lenses or the ophthalmoscope, in order to ascertain the cause of the deficiency of visual acuteness.

Ametropia or lessened accommodating power is indicated when some of the types are seen clearly at the distances marked above them, but other types are not seen clearly at their distances. In such cases, the refractive power of the eye does not maintain correspondence with the relations which are preserved between distance and size in the types. If an eye can read the 1-foot type at the distance of 1 foot, the 1½-foot type at a foot and a half, but cannot read the XX-feet type at 20 feet, and other larger types at their respective distances, myopia is indicated; while if the XX-feet type can be read at 20 feet, but the smaller types cannot be read at their distances, either presbyopia or hypermetropia is probably present.

If deception is attempted, whether of a positive or negative kind, it may often be exposed by subjecting the person under examination to tests by different but adjacent types. If there be no attempt at deception, but an alleged deficiency in acuteness of vision be real, the relations between D and *d* will be preserved when types of such different sizes, as the 20, 30, or 40 feet type, are presented to be read. If V. $= \frac{10}{20}$, it ought to be equally $\frac{15}{30}$ and $\frac{20}{40}$ if other like conditions be carefully preserved; if a different value be given to V., deception of some kind may be suspected. The smaller sized types, Nos. 1 to 3 or 4, should be excluded from the comparison.

The degree of acuteness equally with the alertness of V. are naturally lessened in the later years of life, owing to decreased transparency of the dioptric media, decreased retinal sensitiveness, and other senile changes. But from a table published by Inspector-General Dr. Lawson, comprising a series of observations on 974 persons, it would appear that acuteness of V. gradually declines from a very early age, even as early as fifteen years. The decrease in the instances quoted was independent of diminution in accommodation. If follows that other causes besides senile changes must be sought for to explain the lessening of acuteness of V. with age, should Dr. Lawson's facts be substantiated by more extended observations.

According to a table quoted by Dr. Snellen, deduced from a series of observations by T. v. de Haan, of Utrecht, on 281 persons of ages varying from 7 to 83 years, the state of whose eyes had been previously ascertained to be sound and healthy, acuteness of vision was above Snellen's standard up to 40 years, but began to decline slightly between 20 and 30 years of age, became $\frac{1}{10}$th below Snellen's standard at 50 years of age, and was reduced nearly to $\frac{1}{2}$ at 80 years of age. The actual figures resulting from the experiments, according to the quotation, showed that the average acuteness of vision for ages up to 20 years, the figure 20 being used as a standard of comparison, was as 22·5 : 20; at 30 years as 22 : 20; at 40 as 20·5 : 20; at 50 as 18 : 20; at 60 as 14·5 : 20; at 70 as 13 : 20; and at 80 as 11 : 20.

Snellen's test-types can be readily turned to account in the application of any rule that may be laid down as to a required standard of visual acuteness. Thus, for example, a military friend gives me, as a rule, from the result of his experience, that a soldier to be effective must be able to distinguish clearly a man from any other object at least at a distance of 500 yards under ordinary illumination, as in a moderately clear daylight, and with no more striking contrast of background than what is met with in ordinary fields or moorland. A sentry on an advanced post who could not distinguish an enemy at that distance in front of him would endanger the safety of a force. With such a background as the "sky-line," or any background forming a marked contrast with the object, a man ought to be recognised at 1000 yards. The amount of light reflected from the object looked at relatively to the amount of light reflected from the objects by which it is surrounded, and the character of the background, are always important elements in regard to visual perception, in addition to the size of the visual angle subtended by the object.

The rule for recognition at 500 yards may be applied by means of Snellen's types thus :—Assuming the height of a man to be that at which the height for infantry is calculated in rifle practice, viz., 6 feet, the visual angle under which he would be seen at a distance of 500 yards is 13′ 44″, or nearly 2·7 times the visual angle under which Snellen's types are seen. Recognition of 20′ Snellen on toned paper in an ordinarily lighted room at a distance of 7′ 5″ may therefore be used as a test that one man is capable of distinguishing another man at a distance of 500 yards under the above-named conditions. A man 6 feet in height to be seen under the same visual angle as Snellen's types would have to stand at a distance of about 1375 yards off. But practically at such a distance, owing to the effect of the intervening atmosphere and other circumstances, the man could not be distinguished, although an object having the same visual angle might be seen plainly in a nearer position under adequate illumination.

Measurement of Visual Acuteness when associated with Ametropia.—If a low degree of V. be due to simple uncomplicated ametropia, whatever the nature of the latter, on it being corrected by suitable lenses, normal acuteness of V. will be restored ; if, however, amblyopia, or other complications exist which participate in causing the degradation of V., the acuteness of V. will be only partially improved by the lenses. Whenever, therefore, V. is found to be below the normal standard on first examination, and ametropia to be associated with it, the nature and degree of the latter should be ascertained with a view to its correction, and the acuteness of V. of the eyes should be tested after correcting lenses have been applied to them. In this way only can the true condition of the eyes, as regards acuteness of V., be determined. The acuteness of V. in all such cases should be noted before correction, and secondly, after correction, of the ametropic defect.

WEAK VISION.

There are three kinds of weak or defective vision, which it is necessary for an observer to distinguish from one another in ocular examinations regarding visual acuteness. The first of these is amblyopia, derived from ἀμβλὺς, blunt, obtuse; the second is asthenopia, from ἀσθενὴς, wanting in force; the third is dim-sightedness, or loss of visual acuteness, due to conditions by which the passage of light to the retina is obstructed or otherwise disturbed. The first refers to imperfection in the sensitive recipient elements; the second refers either to weakness in the internal structures which are engaged actively in adapting the dioptric apparatus to the varied requirements for clear vision at different distances, or to a deranged balance of power between them and the external muscular motors of the organ; the third is usually the result of morbid alterations in some of the ocular structures. It will be convenient to consider separately these three conditions which are very distinct in their nature.

I. AMBLYOPIA.

Definition.—Feebleness of vision from diminished acuteness of retinal perception.

Impaired vision thus defined was formerly included with many other morbid conditions of different kinds under the general term "amaurosis."* Amaurosis is now only used to express total loss of vision from annihilation of the function of the visual apparatus, generally due to intercranial disease, but due also to morbid changes of the optic nerve and retina. Amblyopia, therefore, represents partial loss of visual sense; amaurosis complete loss of visual sense, due to morbid changes in the nervous apparatus of the eye.

Causes.—These may be either intrinsic, that is, due to diseased changes originating in the optic nerve itself, its cerebral connexions, or retinal expansion; or extrinsic, when the diseased conditions are induced in sequence to disease of neighbouring but functionally independent structures, such as cerebral tumours and other cerebral diseases giving rise to pressure on the optic tracts or involving them in the morbid processes, sequels of insolation, intra-orbital tumours, diseases of the choroid, and other intra-ocular affections, reflex irritation from branches of the fifth nerve, and others. Amblyopia is also caused by a variety of constitutional disorders which lead to anæmia, impairment of nutrition, prolonged congestion, or to changes of the ocular nervous apparatus brought on probably by morbid materials circulating in the blood-vessels.

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* Amblyopia is sometimes used to express the indistinctness of vision which is directly dependent upon obstructions or diminished transparency in the anterior dioptric media. It is practically more useful to limit its signification to diminished power of sight dependent on morbid conditions of the retina, optic nerve, or brain, without, however, laying down any limitations as to their nature or modes of origin, than to extend it to lowered acuteness of vision due to causes which are obvious to external observation.

These include constitutional states of general debility due to repeated losses of blood from hæmorrhoidal or other sources, as also to excessive debilitating discharges whatever their nature; habitual and inordinate use of tobacco and alcohol, excessive cinchonism, lead poisoning, secondary syphilis, diabetes, albuminuria, and a variety of cachectic conditions. Other causes are mechanical injuries, such as blows about the orbit producing optic paralysis, hæmorrhagic effusion, and retinal detachment. Sudden severe shock, or excessive intensity of light, as from a close flash of lightning, may be a cause of amblyopia or even complete amaurosis.

Lastly, just as retinal perceptive acuteness may apparently be increased in energy in a healthy subject by constant practice at natural objects, so it may be lessened by want of employment, *amblyopia ex anopsiâ*, as sometimes happens by mental suppression of the retinal image of one eye in strabismus, and also, when a corneal opacity exists in one eye, by the patient excluding this eye from binocular vision in order to prevent visual confusion. On the other hand, *amblyopia* may be induced by continued overstraining of the retina, in prolonged work at minute objects, such as very small printed letters and figures, especially if the types and accessories are bad, and the printing indistinct, as they are in some cheap modern reprints of standard works. The ill effects upon the retina are all the more marked, and occur the more speedily, when the person is placed under the influence of circumstances tending to impair his general health, and when at the same time his retina is overstimulated, and irritated by strong artificial and unsteady light or by the bright glare of a tropical sun.

From the variety of causes, above enumerated, which lead to amblyopia, it will be seen that amblyopia should rather be regarded as a symptom than as in itself a distinct disease. It is as a rule the negative to the positive expression "acuteness of vision." In many instances the diseases which give rise to amblyopia are unavoidably obscure, as when they are intra-cranial, so that the effect, which is manifest the amblyopia, can alone be distinguished and named. Again, in numerous cases where the loss of retinal acuteness is functional, as when it is due to anæmia, the excessive use of tobacco, and other similar causes, no objective lesion can be observed under the closest examination. But in numerous other instances, the cause of the amblyopia can be traced and demonstrated, and the affection of which it is a result should then be properly designated.

Symptoms and Diagnosis.—In its mildest forms the patient simply cannot perceive very small objects clearly at any distance. But it may vary in degree from inability to see some of the smallest size types up to inability to distinguish the types of largest size. The feebleness of vision may become aggravated until it is so weak that the patient is not able to see his way about, and the sensitiveness to light diminish until there is complete amaurosis. In moderate degrees of amblyopia type of moderate size in reading is held closer to the eye than usual, in order to obtain larger images, and thus an inexperienced observer is liable to suppose erroneously that the patient is myopic.

Amblyopia exists independently of any refractive fault or diminution in accommodatory power. Either of these conditions may be present concurrently with the amblyopia. If a refractive defect be associated with it, whatever may be its nature, the correction of it will not improve the amblyopia. The effects of amblyopia are felt at all distances for which the eye is adapted, whether near or distant objects are regarded. There is not usually with amblyopia the sense of effort or fatigue that accompanies asthenopia, nor the "blurred vision" of defective refractive power. If the eye is emmetropic naturally, or has been rendered so by suitable lenses, the amblyopic eye will still only be able to see objects under larger visual angles than are essential for visual recognition by another which has normal acuteness of vision. Amblyopia will of course be found to be accompanied by the characteristic symptoms of the particular diseased condition which gives rise to it, when the latter is of such a nature as to be definitely recognised. As soon as the fact of the existence of amblyopia is established, a true diagnosis of its cause should be sought for through a careful study of the history of the case, and by ophthalmoscopic investigation.

The following are also forms of amblyopia :—

(*a.*) **Hemeralopia**, night-blindness, or that condition of weak vision in which the patient can see well in the daytime, but cannot distinguish objects after sunset or in a dim light. It is frequently found among soldiers who have passed from a northern latitude to a tropical station. In these instances it is evidently due to exhaustion of nervous power from over-stimulation by the bright light of the tropical day and the reflected glare from the water of the ocean, unrelieved by the variety of shade and colour which are met with on land, and the consequent inability to perceive objects illuminated by the comparatively weak rays of moonlight. Snow-blindness appears to be of the same nature. The impairment of sensibility of the retina will be proportionably increased if circumstances have induced any scorbutic taint or marked debility in the constitutions of the individuals affected. This description refers to simple functional hemeralopia ; care must be taken not to mistake it for the diminished visual power which co-exists with retinitis pigmentosa, atrophy, and other structural changes of a grave nature in the retina.

Hemeralopia is sometimes simulated, and is reported to be frequently assumed by soldiers in some foreign armies. Various stratagems have to be resorted to for the detection of the imposition if the condition is feigned, for when it really exists as a functional disorder there is no visible sign by which its presence can be proved. This fact should make medical officers very guarded in expressing an opinion that the disorder is simulated, however strong may be the suspicions which they are led to entertain on the subject.

(*b.*) **Nyctalopia**, which is sometimes used as synonymous with night-blindness, really signifies the converse condition of hemeralopia, or that the patient can see better at night than he can during the daytime. In this state the weakness of the retina consists in its being to unable to bear the stimulus of bright light from hyperæsthesia. The normal acuteness of vision may not be materially lowered in subdued light; but attempts to read print of moderate size, or to examine objects in bright daylight, produce all the symptoms of severe photophobia—ocular pain and dazzling, lachrymation, spasms of the eyelids, supra-orbital pain, and general distress. After sundown, or when the eyes are shaded by tinted glasses, the patient moves about with comparative comfort, and sees objects clearly that he could not distinguish in ordinary daylight. The intolerance to the bright light thrown on the retina by the ophthalmoscopic speculum sufficiently indicates the presence of this abnormal irritability; and this may happen in eyes where there have been no previous symptoms indicative of inflammatory action, and in which the fundus seems to be quite free from inflammatory effects. Such cases are occasionally met with among the soldiers who are invalided during the summer for impaired vision from India. In these instances the affection seems to be due to the prolonged effects of tropical glare upon an over-sensitively organised retina, generally associated, however, with a lowered state of constitutional tone.

In the year 1885 a soldier of the Scots Guards was invalided from Egypt for symptoms of nyctalopia. He had had iridectomy performed in both eyes, prior to enlistment. He was probably passed as a recruit in consideration of his being in other respects a physically sound and finely-proportioned man, and because in a subdued light in a closed room he could count the test-dots at the required distance. He was useless in the open air in the daytime in Egypt. The irritating effects of the glare, owing to the loss in both eyes of the natural power of excluding excess of light by the action of the irides, caused a good deal of suffering at the time, and not only induced extreme difficulty of vision when the daylight was strong, which still existed on his arrival in England, but also led to a considerable amount of amblyopia. In full daylight at Netley the acuteness of vision was greatly improved in each eye by the use of a diaphragm with a stenopœic aperture, but no means could bring it to the normal standard.

(*c.*) **Hemiopia. Half-vision.**—Impairment or loss of retinal perception, limited to the outer half of one eye and the inner half of the other eye. A recollection of the manner in which the fibres of the optic nerves decussate at the optic commissure explains how any cause, pressure or other, impairing the conductibility of either optic tract, before it reaches the commissure, may destroy visual power in the right or left halves of the two eyes, while the remaining portions of both retinæ retain their ordinary power of perception. The diagnosis can only be made out by noting carefully the field of vision of each eye. The limits of the field of vision sufficiently show the existence of the hemiopia. If the left half of the field of vision of each eye is wanting, loss of power of the right half of each retina will be indicated and *vice versâ*. Hemiopia under any circumstances unfits a soldier for duty in the ranks.

(*d.*) **Scotoma.**—Partial deficiency or total loss of vision in an isolated portion or portions of the retina. Scotomes are occasionally central, or are situated near the retinal centre, when serious amblyopia results, and they sometimes affect both eyes simultaneously. The defect may be a sequela of some local lesion, of retinitis, optic neuritis, or of some form of choroiditis. A dark spot, or spots, appear in ordinary vision, corresponding with the portions of the retina that have lost sensibility to light. The spots move in concert with the movements of the eyes. Besides the amblyopia, central scotoma is usually accompanied with localised disturbance of the power of distinguishing colours, the retina around retaining colour perception in integrity. In some cases a part of the retina may be atrophied, separated from the choroid, or may be seen on ophthalmoscopic examination to be infiltrated with choroidal pigment, or there may be localised exudative deposits, or some clot remaining from blood effusion. In many cases no visible evidence of lesion can be detected, when the affection is probably of cerebral origin. Careful examination of the field of vision is the best guide to diagnosis in these latter instances. There will be a certain constant space or spaces in the field where impairment or complete loss of vision is noticed, and in proportion to the nearness of the scotoma to the region of the macula lutea, by so much the more marked and obtrusive the defect will be, and the more unfit the patient for military service.

II. ASTHENOPIA.

Definition.—Deficiency of ocular strength, or feebleness of vision due to strained, unduly balanced, or irregular muscular action, altogether irrespective of amblyopia, which may or may not be present.

Causes.—Excessive strain, over-fatigue, or atony of the ciliary muscle. Weakness of the internal recti muscles relatively to the demands made on them for converging the eyes to near objects, as in reading. Want of perfect concurrence in the respective actions of the muscles concerned in accommodation and convergence. These causes of asthenopia are often, but not invariably, associated with ametropic states of ocular refraction, viz., hypermetropia, myopia, and astigmatism.

The symptoms which result from the two sources just named are in many respects similar, but the causes being so different in their nature, the diagnosis between the different forms of asthenopia to which they respectively gave rise should be clearly made out, for the principles on which their treatment is to be conducted must be equally different. Two forms of asthenopia are, therefore, distinguished, viz., (*a*) "motor asthenopia" and (*b*) "accommodatory asthenopia."

Symptoms.—The following symptoms are common to both forms of asthenopia. Reading and observation of near objects in general quickly induces fatigue. The effect of continued application of this kind causes a sense of fulness and tightness in the eyes, congestion, uneasiness about the brow, headache, and various forms of nervous disorder. On trying to read, the letters at first appear clear and distinct, but afterwards become blurred, and more or less cross each other (incomplete diplopia). Epiphora, and conjunctival vascular injection, follow if the exertion be continued. The symptoms are relieved by rest, and generally, according to the length of interval of rest, so is the degree of relief.

Diagnosis, beweeen Motor Asthenopia and Accommodatory Asthenopia.— The power of mobility of the eyes must be examined, more especially the power of convergence of the optic axes. In *accommodatory asthenopia* mobility is unimpaired, and the convergence of the optic axes perfect; in *motor asthenopia* the opposite condition exists. The following is a simple way of examining the amount of convergent power possessed by the asthenopic eyes. An object, such as a ruler, is held up before the face in a line midway between the eyes, about the distance of a foot off. This is slowly moved toward the face, and when only half a foot off, attention is paid to ascertain if one of the eyes becomes unsteady and turns outwards. Should this happen after repeated observations, it shows that the internal rectus of the deviated eye is too weak to keep the eye in an inward direction. If the eyes be free from motor asthenopia they will converge together symmetrically to the last limit of convergence. Another plan is to shade one eye, and to direct the other at some object; if *motor asthenopia* be present, the covered eye will be moved by the stronger external rectus muscle, and turned more or less outwards. The relative strength of the converging and diverging muscles may be determined by testing their power of counteracting the deflection of rays which is caused by applying prismatic glasses of known degrees of strength before the eyes. (See "Prisms," p. 32.)

The symptoms of motor asthenopia were attributed by Von Graefe to "insufficiency of the recti interni muscles," and he gave the following as a test of the precise amount of insufficiency. A prism with a refracting angle of about 12°, is to be placed before one eye with its base horizontally downwards or upwards. The image of an object looked at by the two eyes will then be displaced upwards or downwards so far as the eye that has the prism before it is concerned. There will be vertical diplopia. If under these conditions a line with a dot marked upon it near its middle be looked at by both eyes at a distance of about a foot from the face, and a single line is still seen, though elongated, with two dots upon it, one above the other, no insufficiency was supposed to exist, as the internal straight muscles are obviously still acting in concord; but if two lines are seen, each with a dot upon it, though at different elevations, the separation was regarded as a proof of insufficiency. Supposing the horizontal diplopia results from relative divergence of the optic axes, so that the two images are crossed, the distance at which the two lines were separated apart was taken as the indication of the amount of the insufficiency of the internal recti. The strength of the prism which with its base inwards would then produce fusion of the two lines, gave the exact measure of the insufficiency. The accuracy of these views regarding "muscular insufficiency" have, however, been questioned by late observers, and other explanations, which appear to be far more satisfactory, have been advanced to account for the facts observed in the experiments mentioned. It is not, however, necessary to enter more fully into the subject here.*

(*a.*) *Motor Asthenopia* usually co-exists with *myopia.* From the closeness with which the myope regards objects, the internal recti m. are kept on a constant strain, and in certain cases this strain speedily induces exhaustion of muscular energy. There is not a corresponding amount of exertion of the accommodatory function, so the normal balance of action between the two functions of accommodation and convergence is broken. In high degrees of myopia, in young persons, there may be no demand at all for accommodation while the strain of convergence is very considerable. When the distance point of distinct vision is only a few inches off, the myope will read and work at that distance, in which case no accommodation will have to be exerted, but for the sake of single vision there must be the necessary convergence. Exhaustion follows this excess of strain on the muscles of convergence, and the loss of the support that they should normally obtain from the harmonious cooperation of the functions of accommodation favours its occurrence. If the patient, to counteract the effects of this exhaustion, increases his efforts to maintain the convergence of the eyes instead of giving them the necessary amount of rest, the pain and other symptoms of motor asthenopia follow. If neglected, this state of things may lead to permanent strabismus. The patient, in order to prevent the annoyance of the partial *diplopia* produced by the two eyes, owing to their unsteadiness, not seeing near objects precisely in the same direction, will use one eye only; the other will move outwards, and, if habitually unemployed, not only will squint be permanently established, but the eye will be rendered amblyopic. This has been more fully explained under Myopia, at p. 39.

(*b.*) *Accommodatory Asthenopia.*—The cause of this form of *asthenopia*, namely, want of sufficient power in the muscle of accommodation to meet the demands made upon it, at once shows that whatever condition of the eye induces an excessive strain on this muscle relatively to its general tone and development must aggravate, even it has not originated, the defect. Hence its constant co-existence with *hypermetropia*, taxing so unceasingly, as this form of ametropia does, at all distances, the accommodatory effort unless artificially assisted ; its frequent occurrence also with unaided *presbyopia*, when work on small objects at near distances is persisted in ; and its aggravation in degree if astigmatism be, with the varying struggle of accommodation which it leads to, superadded. There is also in accommodatory asthenopia a derangement of the normal cooperation of the functions of accommodation and convergence by which the asthenopia may be aggravated, but the disturbance arises from a different cause to that which originates it in motor asthenopia. In the latter form, as already mentioned, the action of convergence surpasses that of accommodation ; but in accommodatory asthenopia, especially when it co-exists with hypermetropia, the accommodation has to be exerted in excess of the convergence. Here also the loss of the support which springs from the concurrent and even working of the muscles concerned in accommodation and convergence no doubt augments the asthenopia and the difficulties of the patient. After he has been reading or writing for a time, or working intently at any close work, the objects looked at become indistinct, and if only stronger exertion is made to get clear images, instead of sufficiently resting the eyes, the symptoms elsewhere described are produced. These symptoms are aggravated by anything that deranges the general health and nervous system, or lowers the strength of the asthenopic patient. But there is not the tendency to eversion of the eyeball that there is in motor asthenopia. Moreover, accommodatory asthenopia is relieved by convex glasses, in most cases is removed by them when they are of suitable strength, and these would only add to the difficulties of the motor asthenopia of myopes.

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* Full explanations of the facts which were relied on by Von Graefe as proofs of insufficiency of the internal recti muscles, now generally acknowledged to have been erroneously relied on, may be found in the last of the admirable lectures which were delivered by Mr. Brudenell Carter, at the Royal College of Surgeons, on "Certain Defects of Vision." These lectures were published by Macmillan and Co., London, 1877.

Loss of adequate power in the ciliary muscle and subjectiveness to asthenopia may be brought about by other conditions than those of hypermetropia, presbyopia, and astigmatism. Irritation from constant occupation at near objects, spasm, general debility, hysterical states, all become inducing causes of accommodatory asthenopia when the ciliary apparatus is subjected to efforts out of proportion to its strength.

Treatment of Asthenopia.—Asthenopia admits of treatment and often of cure. The ocular conditions which lead to its production, point sufficiently to the means which should be adopted for its relief. If the eyes of the patient are found on examination to be ametropic, the kind of ametropia must be ascertained, and the defective refraction corrected in the manner already described in the chapters on myopia, hypermetropia, and astigmatism. If the patient have become presbyopic, relief must be afforded as explained under presbyopia. At the same time the relations between the convergence of the eyes and the accommodation must be considered, and as far as practicable a normal balance established between them. The employment of the eyes must be regulated, so that while, on the one hand, irritation and fatigue are obviated by the prevention of an excessive demand on the muscles of accommodation and convergence, especially under unsanitary conditions, such, for example, as sometimes are met with when printers are employed in setting up small types in close ill-ventilated rooms by gaslight, and by avoiding excessive strain of the eyes as occurs when persons work at small objects, writing, drawing, &c., in tropical countries with ill-judged exposure of the eyes to the direct solar glare; on the other hand, the weakening effects of abstaining from all proper employment of them are avoided. If there be weakness from constitutional disorder of any kind, its influence on the asthenopia of the patient should not be forgotten, but steps should be taken according to its nature to try and remove it, and to restore the natural standard of health.

III. DIMSIGHTEDNESS.

Impaired Vision from Causes which obstruct the Passage of Light through the Eye to the Retina.—Impaired vision, or dimsightedness, the result of lesions which have led to physical changes in the condition of some of the ocular media, especially to diminished transparency, is a frequent cause of rejection of recruits, and a source of unfitness for further military service among soldiers in the ranks. Such morbid changes, when they exist to an extent sufficient to incapacitate men for military service, are usually easy of recognition, either by direct observation, lateral illumination, or ophthalmoscopic observation of the eye or eyes concerned. The particular causes which lead to loss of transparency in one or more of the dioptric media, or otherwise obstruct vision, are as numerous as the disorders to which the various parts of the eye are subject. The after effects of inflammatory lesions affect vision in very various ways and degrees. Slight interstitial cloudiness of the cornea may interfere with acuteness of vision by causing diffusion of the rays of light which traverse it, and consequently in producing confusion of images on the retina; or the opacity may exist to such an extent, especially if it be central in position, as to obstruct the passage of a large proportion of the luminous rays to the macula lutea, and so to prevent all practically useful amount of visual acuteness. Again, the central parts of the dioptric media may be left clear, but the iris may be so contracted and adherent, that the pupil, owing to the smallness of its aperture, will only admit a very limited portion of the beam of light proceeding from such illumined points of the object before the eye, so that its brightness will be lessened to such an extent as to prevent a proper view of it by the observer. Lesions of the eyelids and other ocular appendages, and many other affections external to the globe of the eye as well as internal to it, which need not be mentioned here, will also induce changes which interfere more or less with the visual function. It is with the permanent effects of these lesions, and the influence they exert on sharpness of sight, that the military surgeon has principally to deal, so far as optical fitness for military service is concerned; in their earlier stages such lesions are matters for surgical treatment.

CHAPTER VII.

Regulations regarding Visual Examination of Recruits.—Range of Vision necessary in Recruits.—Order of December 1863 on this Subject.—Principles on which the Circular Test-dots were Formed.—Counting Test-dots.—Target Centres and Bull's-eyes.—Square Test-dots.—Figure Targets for Range Practice.—Visual Angles under which the Target Figures are seen.—Figure Targets Optically regarded. Test-dots and Snellen's Test-types.—Degree of Visual Acuteness shown by Circular Dots at 10 and 5 feet.—By Square Dots at 15 feet.—By Square Dots at 10 feet.—Test-dots only used for Proving the Minimum of Visual Power allowed.—Directions for Mode of using Test-dot Cards.

Regulations on Visual Examination of Recruits.—The instructions, dated 1st July, 1870, for the medical examination of recruits (clause D, para. 3) required that the recruit should be free from defects of vision—that "he sees well." It was further ordered, in para. 8 of the same clause D, that "the special tests for power and range of vision are to be applied to each eye, as directed on the card of test-dots furnished for that purpose." The revised Army Medical Regulations of November, 1878, qualified in a certain degree and explained the foregoing requirement of the recruit "seeing well," inasmuch as while directing by para. 559, p. 90, that men presenting "defects of vision" will be rejected as recruits, it defined in para. 557 that one of the principal points to be attended to in the inspection of the recruit is, "that his vision is sufficiently good to enable him to see clearly with either eye at the required distance." This direction of course implied that it was objects of a certain fixed size, viz., the test-dots, which were to be seen clearly at the distance required. The same directions are continued in paras. 969 and 970 of the Army Medical Regulations of 1885, while, in addition, in para. 986, the mode of testing vision by the test-dot card is fully described.

Under "defects of vision" are obviously included all conditions, whether congenital or pathological, of the eyes and their appendages which interfere with clearness of view of the appointed test-objects at the prescribed distance. The necessity of a proper search for these defects is comprehended in the direction in para. 982, p. 171, of the Regulations last referred to, viz., "The surgeon examines the eyes and eyelids," and is again alluded to in the succeeding para., 983.

Range of Vision necessary in Recruits.—The recruit is thus required to possess a certain range and degree of acuteness of vision; and that he does possess this required range and power of vision is tested by means of the test-dots referred to in the Regulations already quoted. It is necessary to understand what range and power of vision are indicated by these test-dots, more especially as they have occasionally been supposed to be supplied for indicating that a recruit possesses a complete range and perfect acuteness or power of vision.

At first, when the introduction of long-range rifles with graduated aims in place of smoothbore muskets made it necessary to pay particular attention to the range and acuteness of vision possessed by recruits, efforts were made to obtain recruits with full range and perfect acuteness of vision. But it was found impossible to obtain recruits possessing such fine qualities of vision in sufficient numbers, and it therefore became necessary to relax the requirements in these respects. It was then obviously necessary to have some standard range and power of sight fixed, such that the proved possession of them would render men acceptable as recruits, so far as quality of vision was concerned, while the absence of them would render men unacceptable as recruits.

Ultimately a particular limit was determined, and this limit, which then became the regulation standard of visual fitness for army recruits, was published in the following order, a copy of which was issued to each army medical officer :—

Army Medical Department,
3rd December, 1863.

Sir,

His Royal Highness the Field Marshal Commanding in Chief having been pleased to notify

"That men should not be received into the service who do not see well to 600 yards at least, a black centre 3 feet in diameter on a white ground,"

I have the honour to request you will have the goodness to pay strict attention to this command in the examination of recruits. (Signed) J. B. Gibson,
Director-General.

The black centre, 3 feet in diameter, on a white ground, mentioned in the foregoing circular, signified the bull's-eye of the target which was used at that time by trained soldiers in practising with the rifle at distances from 600 to 900 yards. The question then arose how medical officers were to carry out this instruction in examining recruits, there being many manifest difficulties in the way of ascertaining that men could see the actual bulls'-eyes at the required distance under the conditions in which the examination of recruits is ordinarily conducted.

Test-dots for Military Purposes.—I had already suggested in an article in the Army Medical Reports for 1860, the use of black discs, formed on principles explained in the paper referred to, for the purpose above mentioned. I now prepared some of these discs on a card, so that when held at a given distance they formed retinal images of the same sizes as the bulls'-eyes 3 feet in diameter at 600 yards, and having submitted them for approval, they were adopted for effecting the desired object. The size of each of these discs or test-dots was one-fifth of an inch in diameter, and though they were distributed over the card at irregular distances apart, no two adjoining test-dots were placed with a less interval between them than one equal to their own diameter. The distance at which the test-dot card was arranged to be held was 10 feet. This was considered to be a convenient distance, and the diameter of the small test-dot was then found by a simple calculation of proportion, viz., as 600 yards : 3 feet :: 10 feet : $\frac{1}{5}$th of an inch. The visual angle of the dot $\frac{1}{5}$th of an inch in diameter at 10 feet being the same as that of the large bull's-eye 3 feet in diameter at 600 yards, or, in other words, the diameters of the two discs being seen under equal angles, and the two discs therefore being of the same apparent size, it followed, other conditions being alike, that if the recruit could distinguish clearly the small bulls'-eyes at 10 feet distance, he could equally see the 3-feet bulls'-eyes at 600 yards as required. It was only for this purpose that the test-dots were devised,—to test the ability of the recruit to see the 3-feet bull's-eye at the prescribed distance, not to test the nature of any refractive or other visual defect which might in particular instances prevent the miniature bulls'-eyes from being counted.

Counting Test-dots.—It was found by practical trials that recruits could not be relied on for counting correctly more than seven or eight of the discs at a time, even though they were all separately visible to him, and the small bulls'-eyes, or test-dots, were therefore at first limited to this number. But it was found that the limit in number was made known to the recruits by the "bringers," so that the recruits, probably judging by the amount of test-dot card exposed, occasionally guessed the number submitted to them, although they did not see the dots distinctly.

To counteract this trick, a larger number of dots was printed on the test-dot card, and they were so disposed that by means of a covering card of a certain shape, which could be shifted into six positions in front of the test-dot card, twenty-five variations in the number and relative positions of the dots could be obtained without exposing more than seven or eight at a time. The test-dot card was ultimately adopted in this shape, directions for using it being printed on the back.

Change from Circular to Rectangular Bulls'-eyes. — Subsequently the circular bulls'-eyes and centres of the iron targets were changed to rectangular bulls'-eyes and centres. This was not done for any purpose connected with eyesight in musketry practice, but simply in consequence of it being found more easy to paint the bulls'-eyes and centres accurately upon the targets, either singly or in combination, when they were cast with vertical and horizontal lines marked upon them in small squares. In January, 1868, a corresponding change was directed to be made in the test-dots. It was ordered that the 2-foot square bull's-eye should be seen by recruits at a distance of 600 yards, the same distance as that at which, by the circular of the 3rd December, 1863, the circular 3-feet bull's-eye had been ordered to be seen. In arranging the test-dots to comply with this order, it was found convenient to have the dots made one-fifth of an inch square in size. To apply them as tests for carrying out the order respecting range of vision, they had to be placed at a distance of 15 feet from the recruit. As before, the distance at which the test-dots were to be held was determined by a simple calculation of proportion, viz., 2 feet : 600 yards :: $\frac{1}{5}$th of an inch : 15 feet. In other respects the square test-dot cards were similar to the former round test-dot cards.

Return to Circular Bulls'-eyes.—In March, 1876, the shapes of the bulls'-eyes and lines enclosing the centres on the service targets were again changed by general order. The rectangular outlines were discontinued and the circular outlines were reverted to. Not long afterwards, a corresponding change in form of the test-dots was adopted (W. O. Form I, 1220.) This card of circular test-dots now forms the authorised test for service purposes in recruit examinations at the present date (1885).

Test-dots of W. O. Form 1233.—In 1875 a distinguishing War Office number was given to the cards of square test-dots, so as to include them in the list of Forms authorised for issue in the public service. They were marked W. O. Form 1233, and under this designation were referred to in the revised Army Medical Regulations of 1878.

From an optical point of view, square bulls'-eyes and centres are defective as means of measurement of the respective visual merits of marksmen. As the aim of the marksman is directed on a given point, and as that point becomes the anterior pole of the visual line, the merit of a particular shot can only be fairly tested by an estimate of the radial distance from the central point of vision at which it has struck the target. It is evident that with square bulls'-eyes and centres, the shots of two men striking at the same distance from the central point may be differently estimated. If the shot of one has struck in the direction of the diagonal of the 2-feet square bull's-eye at a distance of 15 or 16 inches from the central point, it would count as a "bull's-eye," while another shot at precisely the same distance from the central point, but in a direction perpendicular to one of the sides, would be outside the bull's-eye, and only count as a "centre."

Target-centres and Bulls'-eyes.—In rifle drill instruction a distinction is made between a bull's-eye and a centre. The technical term "centre" might easily lead to misconstruction, as it does not occupy the position of the real centre of a target. The bull's-eye in the range-targets hitherto in use has consisted of a black figure on a white ground, varying in size according to the distance at which the target has been placed, and according to the class of marksmen firing at it. Outside the bull's-eye was a white space bounded by black lines. The space within these lines and between them and the bull's-eye was called the *centre*. Outside these lines was the remainder of the target, and in target practice, the stroke of a bullet which neither hits the bull's-eye nor the centre, but hits the target beyond their limits, is spoken of as an "outer." When the rectangular bulls'-eyes and centres were in use, the size of the bull's-eye aimed at by recruits and soldiers of the 1st Class was 2′ × 3′, used for distances varying from 450 to 800 yards; for the 2nd Class, 2′ × 2′, for distances from 250 to 600 yards; of the 3rd Class, 2′ × 1′, for distances from 50 to 300 yards. The size of the bull's-eye ordered to be adopted as the test for vision was therefore that of the bull's-eye used by marksmen of the 2nd Class. When the circular bulls'-eyes and centres were re-introduced, the diameter of the bull's-eye for the 3rd Class was 1 foot, and was fired at by recruits from 100 to 200 yards, and by trained soldiers from 200 up to 300 yards; of the 2nd Class was 2 feet in diameter, and was fired at by recruits from 300 to 400 yards, and by trained soldiers from 500 up to 600 yards; of the 1st Class was 3 feet in diameter, and was fired at by recruits from 500 to 600 yards, and by trained soldiers from 700 to 800 yards (see Rifle Exercise and Musketry Instruction, 1879, Part VI, p. 245, &c.). The black circular test-dots used in trying visual power, had reference, therefore, to the bulls'-eyes used by marksmen of the 1st Class. Still more recently further changes have been made By the latest regulations (Musketry Instruction, Provisional, 1884; and G. O. 38, March, 1885), the bull's-eye on the 3rd Class target, which is fired at by recruits from 100 to 200 yards, is 12 inches in diameter; the bull's-eye of the 2nd Class target, fired at from 300 to 400 yards, is 2 feet in diameter; that of the 1st Class target, from 400 to 500 yards, is 3 feet in diameter. The 3rd Class target is fired at by trained soldiers in their annual course of practice at distances varying from 150 to 300 yards; the 2nd Class target, from 500 to 600 yards; and the 1st Class target, from 700 to 800 yards.

Visual Angles subtended by the Target Bulls'-eyes at different Distances.—There is only exceptional uniformity in respect to the visual angles which the bulls'-eyes subtend at the different distances they are fired at. The 12-inch bull's-eye at 100 yards has a visual angle of nearly 12′ (11′ 28″), and consequently the same bull's-eye at 200 yards, the 2′ bull's-eye at 400 yards, and the 3′ bull's-eye at 600 yards, are all seen under equal angles of 5′ 44″. The 1′ bull's-eye at 300 yards, and the 2′ bull's-eye at 600 yards, are each seen under visual angles of 3′ 50″. The 3′ bull's-eye at 500 yards distance has a visual angle of 6′ 54″, while at 800 yards it has a visual angle of 4′ 18″. The largest visual angle presented by a bull's-eye at any distance is the 1 foot bull's-eye at 100 yards distance, viz., 11′ 28″, and, therefore, having the largest apparent size, should, other things being alike, be the most distinctly visible to a marksman. As by Snellen's standard such plain black objects on a white ground ought to be seen by an eye of average normal acuteness of vision under a visual angle of one minute, or by Burchardt's sight-tests under a visual angle of 2·15 minutes, it follows that in a good light in the open air, if the atmosphere be clear, the tax on visual power in regarding the bull's-eye at target practice as hitherto employed, has been by no means a severe one.

Figure Targets for Range Practice.—A notable change has very recently (March, 1885) been made in the targets used for range practice both by recruits and by men in the ranks at the annual courses of practice. "Figure Targets" and "Head and Shoulder Targets," which were previously restricted to so-called "Field Practices," have now become the ordinary targets for range practice. The bulls'-eyes and circles defining the centres are retained, but are so painted as to be no longer visible to the men aiming at the targets, with one exception, which is in the case of recruits firing at the 3rd Class target, when the bull's-eye is ordered to be marked white. In all other cases a black figure representing the shadow of a man is to be painted on the target, and to be the object aimed at, the bulls'-eyes being only marked in outline. This figure in each target is 6 feet in height, 2 feet across at the part representing the shoulders and upper part of the trunk, and 1 foot across in the parts representing the face and lower extremities. The bull's-eye and centre-line are so marked that although they are not distinguishable by the firer they are visible to markers in the butts near the targets. The respective values of hits upon different parts of the targets remain equal to what they were when the bull's-eyes and centres were visible to the firers, a hit in the centre being valued at three-fourths of a hit in the bull's-eye, and a hit outside the centre, as half the value of one on the bull's-eye. In certain practices hits on the figure only have a value, and the value is equal, whatever part of the figure may be struck. For range practice in the 3rd Class target only one figure is shown, in the 2nd Class target three figures placed side by side, in the 1st Class target four figures, while in the targets for volley and independent firing either six or eight figures are placed side by side according to distance. It may be advantageous in some cases to be aware of the degree of visual acuteness which is required for these figures to be seen at the distances at which they have to be fired at, and this knowledge can be best obtained by ascertaining the visual angles under which they are presented to the sight of a firer.

Visual Angles of Target Figures at different Distances.—The target figures are placed for practice at distances which vary from 100 to 800 yards. The visual angles under which the bulls'-eyes in the several classes of targets are presented to the firers have been already named. The visual angles which the 6-ft. figures subtend at the respective distances they are fired at are as follows:—

Distance.				
100 yards	=	1°	8′	16″
150 ,,		0	45	50
200 ,,		0	34	26
300 ,,		0	23	14
400 ,,		0	17	11
500 ,,		0	13	45
600 ,,		0	11	28
700 ,,		0	9	50
800 ,,		0	8	36

The visual angles formed by the breadth of the figure, both the broader and narrower parts, may be at once determined by the foregoing table, for the visual angles subtended by the parts 2 feet across will be one-third, and by the part 1 foot across one-sixth of the dimensions of the visual angles under which the height of the figure is seen at the different distances specified in the table. In like manner, on three figures being joined together in the 2nd Class target, and four figures in the 1st class target, the visual angles under which the combined broad parts of the joined figures are seen will be simple multiples of the visual angle subtended by the corresponding part in the single figure. In the 2nd Class target the width at this part will be trebled, and will be the same as the height, viz., 6 feet across; in the 1st Class target in which four figures are placed side by side, the width across the body will be 8 feet, and the visual angle will be increased by an extent equal to one-third of the visual angle under which the height of the 6-feet figure is seen at equal distances.

An acquaintance with the sizes of the visual angles subtended by the figures on the targets at the various distances at which they are placed for range practice will enable a medical officer to determine how far any soldier, whose acuteness of vision for distant objects has been previously ascertained, is competent to distinguish them for practice as a marksman, light and other conditions being alike. The fact that the visual angle is greatest in the vertical direction in the 3rd Class target, while it is greatest in the horizontal direction in the 1st Class target, will also call attention to the influence that may be exerted on vision if the eye of the firer happen to be astigmatic in formation.

Figure Targets optically regarded.—It is obvious that from an optical point of view, and also as regards relative merits in respect to accuracy of aim, the figure targets in those practices in which a hit on any part of the figure has an equal value, while a hit anywhere outside it is regarded as a miss, are open to the same objections as the square bulls'-eyes and centres. Optically regarded they are by no means of equal value. A shot at the bottom of the figure, about 3 feet from the centre, cannot have the same optical value as a hit which may be under a foot in certain directions from the centre, and yet is not admitted to be a hit at all in musketry exercise. On the other hand there are certain advantages in the use of the figures: whether single or in groups, they more closely resemble the objects a soldier would have to fire at in warfare than circular bulls'-eyes and centres; and the argument that a hit anywhere will cause a wound which would disable an enemy probably explains the fact of their being estimated at equal values in the musketry practice, whatever their distance from the centre may be, so long as the hit is within the outline of the figure. The men under instruction are still taught to try and hit the centre of the object aimed at, on account of the margin this allows for variations in direction and elevation, and it is in accordance with this principle that the circles representing bulls'-eyes and centres are retained, though they are only visible to the markers in the range practices. They enable the superior quality of the marksman to be shown who, without seeing a distinct bull's-eye to aim at, can place his shot nearest to the centre of the figure or group of figures. Although certain advantages may attend the plan of attaching equal values to hits irrespective of distance from the centre of the object aimed at in some practices, it should not be forgotten that the principle of making no distinction in the value of the shots is not a right one, optically regarded, for it puts different degrees of accuracy of aim, and probably different qualities of sight, all on the same level. A man who only hits the target at the distance of the head or foot of the figure, may not be able to fire more truly owing to some visual defect, and the firer in consequence may relatively be little to be depended on as a practical marksman, especially under different circumstances of illumination and contrast, on other occasions of more importance.

Test-dots introduced among Snellen's Test-types.—About the time that the circular test-dots were introduced, an edition of Snellen's test-types was printed for distribution among the medical officers of the British army.* Dr. Snellen at my request introduced the test-dots among his test-types, and it may be observed that he placed above them the number 54, to indicate the number of Paris feet at which the test-dots ought to be held for testing normal acuteness of vision. At this distance the test-dots would form a visual angle of the 60th part of a degree, which, as already explained, Dr. Snellen has taken as the smallest visual angle under which an object is visible by an eye possessing average normal acuteness of vision under ordinary conditions.

But as all Dr. Snellen's types and figures are rectangular objects, while the test-dots introduced among them are circular, it follows that a difference of calculation was required for the test-dots. The difference between the area of a circle and the area of a square should have been taken into account. The area of a square to that of a circle is as 1 : 0·7854, and taking 54 feet as the distance at which a rectangular object one-fifth of an inch square should be seen by normally acute vision, a circular object one-fifth of an inch in diameter would, in proportion, be only visible by an eye of normally acute vision at a distance of about 43 feet.

If all recruits could read, it would be far better to use types of definite sizes, such as Snellen's, for the examination of vision. The visual acuteness could be definitely registered, or the possession of any fixed standard of power of sight determined. But as by the latest returns (Army Medical Report, 1884) nearly 14 per cent. (13·8) of all the recruits who seek enlistment are unable to read, a simpler test, such as that of merely counting a few spots of certain size at a given distance, is rendered necessary.

Degree of Visual Acuteness shown by Counting the Circular Test-dots at 10 feet.—It has been mentioned that the circular test-dots one-fifth of an inch in diameter when first introduced, were ordered to be held at 10 feet distance from the recruit, this distance, so far as concerned the production of the image on the retina, being equivalent to that of the bull's eye 3 feet in diameter, when seen, as ordered, at 600 yards. As already explained, similar test-dots held at the same distance, are again employed for testing the vision of recruits, and form the authorised standard by which their acceptance or rejection is at present regulated. But it has been shown that under average normal acuteness of vision they should be seen at a distance of 43 feet. Therefore, since 10 : 43 :: 1 : 4·3, it follows that recruits accepted under the limit of the visual test just named, are accepted with $\frac{1}{4\frac{3}{10}}$ths, or nearly one-fourth, of normal acuteness of vision. In other words, if Snellen's test-types were used instead of the test-dots as the standard of visual sufficiency, a recruit would be accepted who could only read the 20-feet type at a little under 5 feet distance (4 feet 8 inches) instead of the full distance of 20 feet.

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* "Test-Types for the Determination of the Acuteness of Vision." By H. Snellen, M.D. Second Edition, Utrecht, 1864.

Visual Acuteness shown by Counting the Circular Test-dots at 5 feet.—It is ordered in the Regulations for the Militia, 1883, p. 32, that a medical officer in the examination of a militia recruit, is to ascertain "that his vision is good, or at least sufficiently good to enable him with his right eye to discern objects clearly at not less than 300 yards;" and it is laid down in the directions on the back of the test-dot card in present use, that the test-dots are to be counted by a militia recruit at a distance of 5 feet, in accordance with the requirement just named. It follows, therefore, that a militia recruit may be accepted who has only half the minimum allowed for a recruit of the regular army, or between $\frac{1}{8}$th and $\frac{1}{9}$th of normal acuteness of vision. If Snellen's types were used as the test, then a recruit would be accepted for the militia by the regulated standard, who could only read the 20-feet type at a distance of 2 feet 4 inches, instead of the normal distance of 20 feet. This equally applies to recruits for all departmental corps.

Visual Acuteness shown by Counting the Square Test-dots at 15 feet.—The rectangular test-dots one-fifth of an inch square had not been introduced when the English edition of Snellen's test-types was published. Had they been, the figure 54 would have been rightly attached to them as showing the number of feet at which they ought to be placed from an eye in proof of normal acuteness of vision. The order required the 2 feet square bull's-eye to be seen at 600 yards, which is the same as requiring the $\frac{1}{5}''$ square test-dot to be seen at 15 feet; for 2′ : 600 yards :: 0·2 inch : 15 feet. But as for normal acuteness of vision by Snellen's standard, they should be seen at 54 feet;[*] it follows that recruits were accepted when these dots were held at 15 feet, with only $\frac{1}{3\frac{6}{10}}$ths of the normal standard (15 : 54 :: 1 : 3·6).

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[*] *Calculation of Distance with respect to Visual Angle.*—The distance at which an object, the measure of whose extreme limits is known, ought to be placed in order to subtend an angle of one minute may be roughly ascertained without difficulty, for the radius of the circle of which that measure forms part under the angle named will give very closely the distance required.

Thus, taking the square test-dot under notice:—If an object 0·2 of an inch in measure occupies 1 minute of a circle, 1 degree of the circle will be equal to 12 inches, and the circumference will be 360 feet. The diameter being equal to the circumference divided by 3·1416, the radius will be 57 English feet, omitting fractions. Therefore, at 57 feet distance the visual angle of the 0·2 of an inch test-dot will be one minute. All the distances in the English edition of Snellen's test-types (1864) were stated in French feet, and as the ratio of English to French feet is 46 : 49, so, omitting fractions, the 57 English feet would be equal to 54 French feet, the number stated above the test-dots in Snellen's tables.

Reduction of Distance for the Square Test-dots by Order of August, 1870.—In August, 1870, the following circular modifying the standard of vision to be determined by the test-dots was issued :—

Recruiting. Horse Guards, 3rd August, 1870.

Circular Memorandum.

With reference to the instructions for the medical examination of recruits, dated 1st July, 1870, it is notified that the medical officer will adhere strictly to the necessity that the vision of the recruit be sufficiently good to enable him to see clearly ; that paragraph 3 of clause D be carefully attended to, but that paragraph 8 of the same clause, as regards short sight, is so far modified that each test-dot on the card now required to be seen distinctly at 15 feet may, till further notice, be tested for a distance of 10 feet only.

CLEM. A. EDWARDS,
I. G. of Recruiting.

By this order a further reduction in visual acuteness took place, for myopic recruits were to be taken who could recognise the test-dots at 10 feet only. The standard of visual acuteness was lowered from $\frac{1}{3\cdot6}$ to $\frac{1}{5\cdot4}$ of the standard of average normal acuteness of vision.

Reduction of required Visual Acuteness limited to that caused by Myopia.—It should be noticed that the circular limited this depression of the standard to cases of myopia, and it threw on the medical officer the responsibility of distinguishing between defective vision due to short sight, and that resulting from other ocular abnormal conditions or disorders. The medical officer was directed to adhere strictly to the necessity of only accepting a recruit with vision *sufficiently good to enable him to see clearly ;* only the range of vision within which myopic recruits were required to see clearly was curtailed. At the present time no special limitation is in force as regards myopic relatively to other recruits. The existing regulations require that the circular test-dots shall be seen distinctly enough to be counted correctly at a distance of 10 feet by all recruits of the regular army alike, excepting those for departmental corps.

Quality of Vision tested by the Dots a Minimum Quality.—It is not to be forgotten that the examination carried out by the card of test-dots is for a minimum quality, and that an unknown number of recruits, probably a large proportion who are passed fit for service under its application, have a range of vision far beyond that which is indicated by the trial. The precise number of men admitted into the service who possess a farther range and higher degree of acuteness of vision than those demanded by the authorised test-dot standard could only be ascertained by testing the full range and acuteness of vision of each individual who is enlisted.

Rules for the Use of the Test-dots.—When employing the test-dots for trying the power and range of vision of recruits, it is important that the rules laid down for the manner of using them should be duly attended to. The following are the directions printed on the back of the test-dot card of the present pattern (No. 27 | Gen. No. 4909. June, 1885).

"Each dot" corresponds, at a distance of 10 feet, with a bull's-eye, 3 feet in diameter, at 600 yards. This is the range of vision required for recruits for the regular army except those for departmental corps.

Directions for using the "Test-dot Card."

1. Place the recruit with his back to the light, and hold the test card perfectly upright in front of him, letting the light fall fully on the card.

2. Measure off with precision 10 feet, in the case of a recruit for the regular army, and 5 feet in the case of a recruit for a departmental corps or the militia, the range of vision required for such corps being only 300 yards.

3. Examine each eye separately. The eye not under trial should be shaded by the hand of an assistant, who will take care not to press on the eyeball.

4. Expose some of the "dots," not more than 7 or 8 at a time, and desire the recruit to name their number and positions; vary the groups frequently to provide against deception.

The Test-dot Card must be kept perfectly clean.

CHAPTER VIII.

Mode of Conducting the Visual Examination of Recruits and Soldiers.—Appliances used in the Examination.—The Examination Room.—Each Eye to be separately Tested.—Defective V. of either Eye causes rejection of a Recruit.—Pressure upon the Eye to be avoided.—Application of Test-dots.—Relative V. of Right and Left Eye.—Procedure if Imposition be Suspected.—Secondary Inspection of Recruits.—Field of V.—Visual Examination of Soldiers.—Application of Snellen's Test Types.—To ascertain the Sources of Defective V.—Preliminary Inspection of the Front of the Eye.—Lateral Illumination.—Detection of Myopia.—Hypermetropia.—Astigmatism.—Amblyopia, how to distinguish from Myopia.—Amblyopia complicated with Myopia.—Disqualifying Degree of Myopia, Hypermetropia, Astigmatism, and Amblyopia.—Weak V. from other Causes.—Colour-blindness.—Degree of M. which does not disqualify for Service.—Visual Quality essential for Soldiers.—For different parts of an Army.—Degree of M. which disqualifies for Service.—Myopic V. of $\frac{1}{22}$, or 1·75 D.—M. = $\frac{1}{32}$ or 1·25 D.—Ametropia in Continental Armies.—Spectacles not worn by soldiers in the Ranks.—Spectacles at Musketry Instruction.—V. necessary for Commissioned Officers.—Declaration concerning V. by Candidates for Commissions.—Blindness of One Eye.—Quality of V. required for the Line.—Correcting Glasses at Visual Examination.—Attempts at Deception.—Quality of V. required for Medical Staff.—For the Royal Artillery and Engineers.—For Special Instruction at School of Musketry.—For Royal Navy.—Impaired Vision of one Eye in a Soldier not a cause for Discharge.—Aiming with the Left Eye.—Detection of Simulated Impairment of V.—Assumed Blindness of One Eye.—Modes of Detection.—Case in Illustration.—Assumed Defective V. of Both Eyes.—Modes of Detection.—Case in Illustration.—Simulation of Defective V. seldom attempted by Soldiers.

1. **Visual Examination of Recruits.**—The visual examination of a recruit by the test-dots need not occupy, under ordinary circumstances, more than a few seconds of time. When it is considered necessary, for special reasons, to determine further the quality of

vision of a recruit, as when the evidence afforded by the test-dots leaves some ground for doubting its accuracy, the additional examination may perhaps occupy 10 or 15 minutes. It is best therefore to allow the recruit to dress himself before the visual examination is begun, and to make it after the rest of the inspection of the recruit has been completed.

2. **Appliances for Visual Examination.**—If a particular examination of the quality of vision of a recruit is required, it must be made in the same manner as the visual examination of a soldier who is already in military service. The ordinary ophthalmoscopic and optical case is sufficient, in conjunction with the types and dots, for proving the quality of vision possessed by a soldier in all ordinary instances. For special purposes a complete case of trial lenses is necessary. Full sets of lenses afford facilities that cannot be obtained by any other means for solving complicated cases and detecting attempts at imposition, and are therefore especially useful in general and invaliding hospitals, to which such cases are commonly sent for decision. They also afford the means of proving the existence and estimates of abnormalities of refraction, or amounts of loss of accommodatory power, which have been otherwise diagnosed, by positive correction of the defects.

3. **Examination Room.**—All rooms in which the examination of recruits is conducted should be well lighted. This is especially important in testing vision. The light falling on the test-objects to be looked at should as nearly resemble the condition of ordinary external daylight as possible. At the same time the eyes of the men to be examined should be habituated to the degree of light prevailing for some minutes before the examination is made. The test would not be an accurate one if it were suddenly applied to a man who had just left a place that was either much darker, or more brilliantly lighted, than the examination room.

It is a matter of convenience and also a means of saving time to have some lines, showing distances in feet, permanently marked in ink upon the floor of the room in which Snellen's types or the miniature bulls'-eyes are used. Whenever the space is available the distance should extend at least to 20 feet. The addition of a simple stand for suspending a table of Snellen's types at the end of the 20′ range is also useful. They should be suspended on a level with the eyes of the person to be examined.

In conducting the examination the soldier or recruit is placed with his back towards the window or source of light, so that while his eyes are in relative shade there is a full illumination of the types or dots by which his sight is tested.

4. **Separate Examination of each Eye.**—It is always necessary to test each eye separately. It will not often be found even under healthy conditions that the absolute refractive qualities of the two eyes of the same person, independent of accommodatory exertion, are precisely alike; but in defective conditions of vision the difference between the two eyes is usually more marked. It has not unfrequently occurred that a man has been blind in one eye without

knowing it, until attention has been directed to each eye separately by optical examination.

5. **Defect of Vision in either Eye of a Recruit.**—Under existing rules, the existence of defective vision or disease in either eye is a cause of medical rejection of a recruit seeking enlistment. Though the right eye may be sound, if the vision of the left eye be so defective as to prevent the recruit from being able to count the test-dots with it, and the defect is the result of former diseased action, not simply of conformation, the orders are that he must be rejected. He must see clearly with either eye at the regulated distance. In the former days of long service with the colours, the chances of the sight of the sound eye becoming independently affected by disease originating in the exposure and causes incidental to military service, and of the man thus becoming completely disabled for duty, and entitled to claim a pension, doubtless had an influence in determining the rule that not only the right eye, but the left also, of a recruit should be ascertained to be up to the authorised standard of visual acuteness before he is passed fit for acceptance as a soldier.

6. **Pressure on the Eye.**—In examining the eyes separately, an assistant should cover the eye not occupied in regarding the object, and not the man himself. If the man be allowed to close it, he will probably, from carelessness or nervousness, exert undue pressure on the globe, disturb its condition for clear vision, and cause delay until this disturbance is recovered from. The assistant who covers the eye should be taught that if any pressure be made it should be limited to the margin of the orbit. The object is simply to exclude light by closing the lids or shading the light with the hand; the eye itself should not be pressed upon. If undue pressure have been made, it will be necessary to wait a minute or two until the eye has recovered its normal state and all mistiness of vision has disappeared before applying the test for visual power.

The eye which is to be prevented from seeing should be covered by the palm of the hand of the assistant, formed into a hollow for the purpose. If the fingers are employed, they are apt to press upon the globe, and there may inadvertently be vacant spaces left between them; and either accidentally, or intentionally taking advantage of the opportunity, the eye not under examination may look through one or other of these openings.

If a trial case of lenses be available, it is still better to use the spectacle frame, and either a ground glass or opaque metal disc, both of which are supplied with such cases, in front of the eye not under trial. Not only is pressure on the globe thus prevented, and all chance of the person seeing through chinks obviated, but there is no tendency for the patient to exclude the eye from vision by forcible closure of the eyelids.

7. **Application of Test-dots.**—If the man under examination be a recruit, as soon as he is dressed and placed in position, the test-dots are held upright before him at the prescribed distance—10 feet in the case of a recruit for the regular army, and 5 feet for militia and departmental corps recruits—and he is asked to state the

number of dots exposed to his view, in the manner already explained at page 138. He should be required to count and describe the positions of two or three series of dots with each eye, and if he replies readily and satisfactorily, so far as power of vision is concerned, he is fit for service.*

8. **Rejection of a Recruit.**—If the recruit should make repeated mistakes in counting the number of dots presented to him at the prescribed distance, and there is no reason for suspecting that he is doing otherwise than his best to try to see them clearly, especially if he should succeed in counting them correctly when they are held at some point nearer to him than the prescribed distance, he is then rejected as unfit for service on account of "defective vision." The regulations do not require that the nature or degree of the defect should be particularly stated as regards recruits at their first inspection.

9. **Relative Visual Acuteness of the Two Eyes.**—As recruits in aiming and firing practices are taught to use the right eye only, the left being closed, it seems worth consideration whether it is necessary to insist on men seeking enlistment having an equal range and power of sight in the left as in the right eye, particularly under a system of engagement for short service. Compliance with the authorized standard of visual power does not exclude a man who has simple myopia of about 1·5 D, or $\frac{1}{24}$. And supposing this to be the degree of M. of his right eye, although the M. were as high as 3 D, $\frac{1}{13}$, in his left eye, there hardly seems to be any valid reason against accepting him as a recruit. Even if the visual acuteness of the left eye were lowered by the myopia being complicated with astigmatism, so long as the visual defect is one of refraction only, not one of any morbid origin involving a liability to recurrence of the disorder, it would not prevent him from seeing pretty well for certain distances, and of doing ordinary duties in the ranks and in marching, and there hardly seems to be good ground, therefore, under the present system of using the rifle, for rejecting him as a recruit if he be eligible in all other respects.

The quality of vision of the left eye seems to be regarded as of minor importance in the case of recruits for the militia, for it is specified, with regard to the medical examination, that one of the principal points to be attended to is that the recruit's vision is good, or at least sufficiently good to enable him with his *right* eye to discern objects clearly at not less than 300 yards, while no quality of vision is referred to as regards the left eye.—(Regs. for the Militia, W.O. 1883, Part I, sect. 2, p. 32.)

10. **Defective Vision from Loss of Transparency in some of the Anterior Dioptric Media.**—Diminished translucency of the central

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* The following regulation on the application of test-dots is given in paragraph 986 of the recently published Army Medical Regulations of 1885. "In examining a recruit's vision he will be placed with his back to the light, and made to count the dots and describe their position at the distances specified on the test-dot card, first with both eyes and then with each separately; the medical officer will manipulate the card, while the assistant covers each eye alternately with the flat of his hand."

portions of the cornea consequent on keratitis, diffused deposit of lymph on the capsule of the crystalline lens after iritis, and indeed, cloudiness of the anterior media of the eye from any cause, even though they may not exist to such an extent as to be readily obvious to external observation, cause indistinctness of vision from the diffusion of the rays of light by which the structures concerned happen to be traversed. If the loss of transparency is not considerable, the circular test-dots in present use may be counted at a distance of 10 feet in a good light, but it may be found that a recruit cannot count them beyond that distance. It is questionable, unless there is an urgent demand for recruits, whether a man should be regarded as fit for military service under such conditions, especially if the right eye is concerned, although he is able to count the test-dots at the prescribed distance. It is not merely that a maximum limit of 10 feet in counting the test-dots represents rather less than one-fourth of Snellen's standard of visual acuteness, but in a large proportion of such cases a liability to recurrence of inflammatory action exists, and should this take place an aggravation of the existing defect is almost inevitable.

11. **Procedure when Imposition is suspected.**—In the British service, as recruits are for the most part men voluntarily seeking enlistment as soldiers, not like the majority of conscripts in Continental armies trying to escape enlistment, if any efforts at all are made by them to practise imposition, they will probably be directed to the concealment of any defects of vision they may labour under, rather than to their exaggeration.

If, however, there is cause for suspecting that the man who has volunteered for enlistment has changed his desire on the subject, and that he is trying to escape from the bargain he has so far entered into by assuming a defect of visual power which does not exist, he must be subjected to further tests before he is pronounced unfit for service on this account.

12. **Visual Examination at Secondary Inspection of Recruits.**—Many instances have occurred in which a recruit at first examination has been passed fit in respect to visual power and range, but on being subjected to secondary inspection, has been found unable to count the test-dots accurately at the proper distance with one or other eye, or even with both eyes. At the secondary inspection, when the test-dots are placed before the man, he may perhaps give a succession of wrong replies as to the number of dots exposed to his view, and in some instances under such circumstances is at once regarded as unfit for service. Great caution should be exercised in such a case as to the rejection of a recruit. The presumption is certainly that he was properly tested at the first examination, and that for private reasons he does not choose to count the test-dots correctly at the secondary inspection. Unless there is some evident ocular defect which has obviously been overlooked at the former inspection to substantiate the man's statement, a case of this kind is calculated to excite strong suspicion of the disability being feigned, and systematic steps should be taken to ascertain whether the man's

statements are true or false. This can be done by ascertaining the man's alleged acuteness of vision when the test-dots are placed before him, and then comparing it with the results obtained from the application of other test objects, Snellen's types, for example, as elsewhere explained.

The following special direction on this point appears in the recently published Army Medical Regulations of 1885, para. 987 :—"A recruit whose vision has been tested and pronounced good on a primary examination, will not, through his own declared inability to see the test-dots on secondary examination be rejected, unless the approving medical officer is satisfied that the man's vision is really defective and no deception is being practised by him."

13. **Field of Vision.**—It is important that a recruit should not only possess sufficient central acuteness of vision, but that he should also have his field of vision complete in both eyes. Loss of the outer or temporal portion of the field of view of either eye from any cause especially unfits a man for military duty, for it disables him from noticing and consequently from properly steering his way among the objects by which he may be surrounded on the defective side. A considerable portion of the lateral field of view belongs solely to the eye on the side concerned, and a deficiency in it is not in any degree supplied or compensated for by the eye on the opposite side. The temporal portion is not a part of the field of view which is common to both eyes, and should this portion be absent, objects on the side concerned would not attract observation or attention so long as a soldier may be marching and looking directly forward. The manner in which the existence of deficiency in part of the field of vision is to be ascertained, has been described elsewhere (see page 7).

14. **Visual Examination of Trained Soldiers.**—When it is necessary to determine the acuteness of vision of a soldier already in the service, the general manner of conducting the examination is the same as with the recruit, only the test-types should be used instead of the test-dots. The trial by the test-dots at a prescribed distance, as before explained, has been specially ordered for men seeking admission into the army. In the cases of trained soldiers already serving, a closer and more complete examination is required, as important issues depend on the decision at which the surgeon may arrive. The question usually submitted to the medical officer is whether the inefficiency of a soldier who shows himself to be a specially bad shot at particular distances at the range practices, or in the field practices, at the annual course of musketry instruction, or who shows himself incapable of judging distance with an approach to correctness, is due to some visual defect or not. The nature of the defect, if defect exist, and the extent to which it disqualifies the man for duty, have therefore to be ascertained and stated with accuracy.

15. **Use of Snellen's Test-types.**—In such cases the acuteness of vision must first be determined, and this is very easily done by Snellen's test-types or test-figures. The mode of ascertaining and

expressing the acuteness of vision by these objects has been explained at page 116.

16. **Vision not Defective.**—If these tests are so answered as to show the man under examination possesses average normal acuteness of vision, or a near approach to the average, all morbid states of the eye, such as limitation of the field of vision, as well as disorders of its appendages being understood to be excluded, the subjects of complaint are manifestly not due to visual defect.

17. **Procedure if Vision be Defective.**—If the acuteness of vision is proved to be considerably under the average, the cause of the deficiency must be ascertained. The mode of proceeding is the same in such a case as it is in the ocular examination of a recruit who has shown want of ability to count the test-dots at the prescribed distance, and whose apparent visual defect is suspected for some reason or other to be assumed.

In the first instance, particular and special attention must be paid to the examination of the anterior ocular structures. The cornea, anterior chamber, iris, and crystalline lens of the affected eye should be subjected to minute observation. In the case of a recruit, defects may possibly exist in these structures sufficient partially to obscure vision which were not perceived in the observation of the eyes made at the general inspection, although this could hardly occur if the tests for eyesight had been properly applied. They may equally exist in the case of a soldier serving in the ranks without being visible by ordinary observation as the result of some inflammatory action to which the eyes have been subjected. This preliminary inspection is important, and should invariably be made. Considerable time is often wasted afterwards when it has been neglected.

18. **Lateral Illumination.**—The superficial examination is very rapidly made by *lateral illumination*, and indeed can only be thoroughly accomplished by its means. Lateral illumination signifies lighting up the parts required to be observed by concentrating upon them a pencil of rays cast in an oblique direction. The man is brought near the window of the room, one of the bi-convex object lenses in the optical case is placed vertically near the outer angle of the eye under observation in such a way that the light passing through it is made to converge upon the cornea, or through the cornea on the iris or lens, and the condition of any of these structures is then examined by the spectator standing in front. This lateral illumination is of course more brilliantly seen when the flame in the ophthalmoscopic room is used as the source of light, but is sufficiently marked by solar light on any ordinarily clear day. By these means the slightest roughness of the surface of the cornea, interstitial haziness, minute ulcers, or the remains of them, fine exudations at the margin of the pupil, posterior synechiæ, commencing cataract, are made most obvious to sight, while the pencil of rays at or near its focus is made to play upon each structure at pleasure. Nothing can be more beautiful than the perfect precision with which opacities of the cornea and lens, adhesions of lymph to

the capsule, and other morbid changes, some of which are scarcely perceptible under ordinary observation, become defined by light thrown laterally upon them in the manner just described. If minuter observation be required, the objects while thus illuminated by a lens held in one hand may be magnified by a second lens held within its focal distance by the other hand in front of the eye, without impairing their brilliancy or distinctness of outline. A little practice will enable the operator at one and the same time to direct the apex of the luminous cone proceeding from the lens held between the thumb and forefinger of one hand upon any point of the anterior segment of the eye at pleasure, while he so adjusts the lens held between the thumb and forefinger of the other hand in front of the eye as to obtain the enlarged view of the parts thus illuminated which he wishes more particularly to examine.

A sufficient explanation of the impairment of sight will sometimes be found in this preliminary examination of the eye; but if nothing abnormal can be thus detected, the examiner must proceed further, with a view to discovering the source of the defective vision under which the recruit or soldier appears to labour. It may be due to ametropia, astigmatism, amblyopia, or disease of some of the structures constituting the fundus of the eye.

19. **Detection of Simple Myopia.**—The recruit who has not been able to count the test-dots at the distance of 10 feet is found able on examination to count them at some distance short of it. Equally the soldier who has not been able to read the larger types at the proper distances, is found able to read the Nos. 1 or 2 type at or near the distance of 1 or 2 feet respectively from the eye. The external signs described in the general remarks on myopia will probably at once cause the surgeon to judge that no simulation is being practised, and indicate the nature of the affection he has to deal with. The shortest way is at once to use the convex spectacles, and establish the diagnosis as explained in the section on Myopia; but the refractive condition of the eye should always be objectively determined by the ophthalmoscope in the manner described in the third chapter of this work. This applies to every case of suspected exaggeration or simulation, for it enables the surgeon to arrive at a conclusion on the point which it is out of the power of the man himself to control.

20. **Detection of Simple Hypermetropia.**—The difficulty which the hypermetropic recruit or soldier exhibits in recognising the types and dots at any distance, and the form of the eye, will probably lead the surgeon to suspect the affection under which the man is labouring. The diagnosis should be established objectively by the ophthalmoscope as well as by the convex spectacles, as already explained in the section on Hypermetropia.

21. **Detection of Astigmatism.**—If the man under examination has exhibited hesitation or particular difficulty in recognising the letters or counting the dots at any distance, and the tests for simple hypermetropia and myopia are not readily responded to, the existence of astigmatism may be suspected. The man should be then

tried by Snellen's 20-feet vertical and horizontal lines or dots, and should be subjected to ophthalmoscopic examination in order that the diagnosis may be established by the method explained in a previous part of this work. The method of proceeding for determining the kind and degree of astigmatism, supposing its presence to be established, has been explained in the special section on Astigmatism.

22. **To distinguish Amblyopia from Myopia.**—If it be found that the smallest sized types and dots cannot be distinctly seen at any distance, and that larger sized type is held nearer than normal to the eye, the recruit is probably labouring under *amblyopia;* he cannot be affected with simple *myopia.* To ascertain if this is the defect he is troubled with, weak concave lenses, when these are at hand, are placed before his eyes. If he now sees distant objects worse than he did before, his defect is almost beyond doubt some form of amblyopia; for the concave glasses which would improve vision if he were myopic, render vision worse in *amblyopia* by diminishing the retinal images. When the convex 10″ spectacles are placed before his eyes, if the man under examination be emmetropic but at the same time amblyopic, he will be able to see the 3′ or 4′ type, or type of larger size, at a distance of 10″ from the lenses, although he is unable to see the smaller sized types at that distance.

The stenopœic hole may also be used for settling the question. If a man be myopic and look through the stenopœic aperture in a metal diaphragm, or through a pinhole in a card at distant objects, he will perceive them far more clearly, while if he be amblyopic, there will be no improvement. A person affected with a high degree of myopia, as an $\frac{1}{8}$th or $\frac{1}{10}$th, will be able to recognise Snellen's moderately sized types No. 7, or No. 8, at double the distance when regarding them through a stenopœic hole that he will be able to do with his naked eye, while a person affected with amblyopia will not be able to see them any farther off by this proceeding.

23. **Amblyopia complicated with Myopia.**—Myopia may be complicated with amblyopia, and it is important to distinguish simple short-sightedness from short-sightedness with this complication. In the latter case, when the 10″ convex spectacles are worn, the subject will see types up to some distance within 10 inches, say, for example, 5 inches. The patient's true far point is then $(\frac{1}{5} - \frac{1}{10}) = \frac{1}{10}$, and if the *myopia* be uncomplicated with *amblyopia,* he will be able to read the 1-foot type at the distance of 10 inches without the aid of lenses. If it be complicated with *amblyopia* he will require the 1-foot type to be held nearer to the eye than 10 inches; he will be only able to read some of the larger types at that distance. Again, simple *myopia* is completely corrected by suitable lenses, and hence a ready mode of establishing an exact diagnosis between simple *myopia,* and *myopia* with *amblyopia* is afforded. Having proved the existence of *myopia* according to the methods already explained, the degree of *myopia* is next determined. The proper concave lenses to correct this

degree are then applied, and with them the simply myopic person will be able to see plainly the variously sized types at their proper distances; but if he be also amblyopic, he will only be able to see types of larger sizes at them, according to the degree of *amblyopia*. By referring to the description of the causes of *amblyopia* it will be seen that the occurrence of *amblyopia*, if extensive, with *myopia* is a grave complication: for it indicates the existence of disease, and not merely peculiar confirmation of the eye. The nature of this disease must be solved by ophthalmoscopic examination.

24. **Regulated Conditions under which Myopia Disqualifies for Military Service.**—If the test-dots cannot be counted 10 feet off owing to myopia, the man under trial is to be rejected as a recruit. Myopia, therefore, when accompanied with V. inferior to ¼ Sn., disqualifies for military service. No special degree of myopia has been fixed on as disqualifying for military service, but the disqualifying degree may be approximately estimated from the extent to which its interference with acuteness of vision is held to unfit a man for military service. This is considered farther on.

25. **Condition under which Hypermetropia Disqualifies.**—The recruit who cannot count the test-dots at 10 feet distance, and whose inability to do so is proved to be due to hypermetropia, by existing rules is disqualified for service. Hypermetropia, accompanied with V. inferior to ¼, therefore excludes from enlistment as a recruit. It must not be forgotten that the disabling effects of H. are more or less felt in both far and near vision, that they increase with age at certain ranges, and that they are apt to be aggravated by anything that weakens the soldier.

Conditions under which Astigmatism Disqualifies for Military Service.—The same rule applies when the disability is due to ametropia of either kind, whatever the degree, when the eye is found to be astigmatic. Astigmatism, therefore, of any form, when it is accompanied with V. inferior to ¼, excludes from enlistment as a recruit.

26. **Disqualifying Degree of Amblyopia.**—The general rule that the test-dots must be counted readily at 10 feet distance by each eye determines the disqualifying degree of amblyopia. Whatever may be the cause of the amblyopia, if it exist to an extent which prevents a recruit from counting the test-dots at a distance of 10 feet from the eye, it disqualifies the man for military service. It is not ordered that the cause of the amblyopia is to be determined in the case of a recruit. The reduction of visual acuteness to one-fourth of the normal standard from amblyopia is more disabling than a corresponding reduction which is owing to myopia or hypermetropia, for the defect in the case of amblyopia does not admit of correction or amelioration by lenses.

27. **Disqualifying Degree of Dimsightedness.**—Loss of transparency in some parts of the dioptric media from previous inflammatory action, will be found in most of the instances comprised under this heading; but whatever the visual defect may be in a given case, or whatever may have been the pathological conditions or lesions which

have led to the dimsightedness, the fitness or unfitness for military service of the subject of it, according to existing rules, is tested in the same manner as the degree of acuteness of vision in other instances. If the affection do not hinder a recruit from counting the test-dots at the fixed distance of 10 feet, it does not exclude him from military service; but if the acuteness of vision is so reduced as to prevent him from counting the test-dots, he is ineligible.

If the nature of the affection should be such as to indicate a liability to recurrence of the morbid action which originated it, in which case an aggravation of the defect might be anticipated, even though the man could pass the test-dot examination, it would manifestly, under the circumstances, be imprudent to declare the subject fit for military service; while the same affection in a trained soldier would hardly justify his discharge from the service on the mere assumption of a similar tendency.

28. **Disqualifying Colour-blindness.**—Colour-blindness is not specially named in any military regulations as a ground of rejection of a recruit for the ranks or for a candidate for a commission in the army, and neither recruits nor candidates for commissions are usually tested in respect to sense of colour. It might, however, if attention were directed to the subject, be comprehended in the general term "defects of vision."

All candidates for employment in the Royal Navy, officers and men, are tested with regard to their capability of distinguishing colours, and if discovered to be colour-blind, the defect would be a cause of rejection. They come under the regulation, before quoted, in para. 1074, of the Queen's Regulations and Admiralty Instructions. This rule includes medical as well as other officers. It is obviously necessary that medical officers should possess normal colour-perception, as they are the usual examiners for colour-sense in others. The conditions which render normal perception of colour in the officers and men of the Royal Navy so important, have been already referred to Chapter V.

29. **Quality of Vision Essential for Soldiers in the Ranks.**—Whatever visual disorder a non-commissioned officer or soldier serving in the ranks may happen to contract, so long as he is left with acuteness of vision equal to that for which recruits are tested, he must be regarded as visually qualified for military duty. If he can read the 20-feet type of Sn. at 4′ 8″, or count the army test-dots at 10 feet, he still has the power of sight which would have sufficed for his admission into the military service. For certain special duties, as for going through the training at the Hythe School of Musketry, a higher degree of visual acuteness becomes necessary.

The remarks regarding the need of a complete field of vision for a recruit equally apply to soldiers in the ranks. Hemiopia, and especially loss of the temporal portion of the field of view, due to causes occurring subsequent to enlistment, afford sufficient ground for the subject being brought forward for discharge from further military service.

30. Quality of Vision Essential for a Marksman at full Rifle Range.—The capacity for becoming a perfectly reliable marksman at all the distances for which a modern rifle can be adjusted, implies the possession of normal acuteness of vision in the right, or aiming eye, from the natural near point of distinct vision up to the remotest distance ; and this faculty can only exist when the eye is emmetropic, or so nearly so as not to exceed 0·5 D, or $\frac{1}{80}''$ of ametropia, and when the accommodation is also normal. At the same time the left eye, or eye not employed in taking aim, ought not to possess less than three-fourths of the normal standard of visual acuteness.

31. Degree of Myopia which admits Recruits by Existing Orders.—As myopia is by no means an uncommon affection, though far from being as common as it is in some foreign countries, it becomes important to be aware of the degree which, according to existing regulations allows a recruit to be passed as fit for military service in the combatant ranks. Uncorrected myopia in a soldier is a grave matter, not only on account of its incapacitating him for the accurate use of his rifle, but also because it may lead to the safety of an important post, which he has been placed on sentry to guard, becoming endangered owing to his limited range of distinct view, especially as daylight diminishes. No set limit has as yet been defined with respect to the degree of M. which incapacitates for service in the English army; but it may approximately be arrived at by experimental observation of the degree of uncomplicated M. which admits of the test-dots being counted at the distance, 10 feet, which, according to order, determines recruits to be eligible for service so far as vision is concerned.

Experimental trials show that persons of equal ages, and still more persons of varying ages, differ considerably in their power of distinguishing the presence of objects, notwithstanding that the objects are obscured by an equal amount of blurring from diffused rays, owing to the effects of myopic conformation of the eyes. This circumstance results from the fact that absolutely perfect definition of a retinal image is not necessary for recognition of an object, at the same time that all the other conditions on which acuteness of vision depends are subject to variations in different individuals. But taking the average of a number of trials, at about the ordinary ages of recruits, I find that persons affected with uncomplicated M. = $\frac{1}{23}$ or 1·75 D, can manage, with each eye singly, to count the test-dots at 10 feet under suitable exposure in good daylight. The test-dots are seen mistily, they appear more or less altered in form, but they can be separately distinguished so as to be counted. The present test-dot standard for vision of recruits, therefore, admits men with a degree of M. up to $\frac{1}{24}$, and whose visual acuteness is less than $\frac{1}{4}$ Sn. $(\frac{1}{4·3})$. It will usually exclude degrees of M. higher than $\frac{1}{24}$.

32. The Qualities of Vision which are needed in different Parts of an Army.—The myopia which would make a man unsuitable for the duties of one arm of the service may not make him unsuitable for another. The myopia which would unfit a soldier for aiming at long ranges, whether with a rifle or a field gun, or for the duties of a cavalry vidette, would not unfit him for the working duties of a sapper or pioneer, or for those of the commissariat and transport corps, or medical staff corps. Just as there are different standards of height, girth of chest, &c., for the men of different parts of the army, so equally necessary appear to be different standards of visual acuteness to fit them for their special duties. Certainly riflemen, artillerists, and cavalry soldiers, "the eyes of the army," should especially be as free as possible from shortsightedness, hypermetropia, and other defects of vision.

What particular degrees of myopia and hypermetropia, however, should exclude men from service in special parts of the army in which very acute vision, and a long visual range, are essentially important, can only be determined after a definition by military authority of the particular requirements in those several parts. It is the province of the military authorities to settle the degree of visual acuteness which is necessary for the military duties and responsibilities demanded from each branch of the military service; it is the province of the medical officer to ascertain with precision that the men possess the degree of visual acuteness which is ordered. At present, in the enlistment of recruits for the British army, the same orders in respect to the examination of vision hold good for all recruits alike, whatever branch of the regular army they may be destined for.

33. Degree of Myopia which unfits for Military Duties in the Ranks.—The circumstances of military service are so different in the British army from what they are in continental armies, the cost as regards the individual soldier is so much greater, that in the selection and acceptance of men for service, remembering too that only one rule exists for all parts of the regular army alike, a far higher standard in respect to visual power may well be looked for in the British as compared with continental armies. In a country in which *conscription* is in force, and very large armies are maintained, it is an object not to allow any men to escape conscription who can be turned to useful account in military service—if not fit for one branch then to utilize them for some other—so that only an extreme degree of M. is allowed to exclude altogether from conscription. In a country in which *voluntary enlistment* and highly paid wages are the rule, it is the object not to accept any who are not fully qualified for the performance of the duties which will devolve on them in the army. And when only one standard exists for all alike, it appears evident that the standard for those parts of the army in which a high degree of visual acuteness is a necessity should be chiefly taken into account in framing rules on the subject, in order that the required degree of military efficiency may be attained. To admit recruits with myopia approaching $\frac{1}{6}$th with which conscripts are admitted in Italy and France, and other countries, or even with $\frac{1}{12}$th. and then to draft them for service as riflemen, would be a wasteful pecuniary outlay in the English army. Experience proves that high degrees of myopia rarely exist without the existence of posterior staphyloma and a tendency for the myopia to increase. Considering, moreover, the amount of military service which is passed by a large proportion of the British army in India, and the ill effects resulting from the over-stimulation of the retina of a myope by tropical light, the expediency of admitting men into the ranks of the army with such a degree of myopia as is compatible with the present test of counting the test-dots at a distance of 10 feet, appears to be very doubtful. It seems to be very questionable whether any man with myopia $= \frac{1}{24}$ ought to be accepted as a recruit; such a man certainly cannot be a desirable recruit for the ranks in which the Martini-Henry rifle constitutes the firearm in ordinary use, or in any part of the service where precision of vision for distant objects is demanded unassisted by correcting spectacles. For parts of the army in which accurate sight is not such a necessity, it would be difficult to lay down any rule as to the limits of myopia, or other ametropic conditions, admissible; for just as the regulations regarding the height, girth of chest, and other physical conditions required in recruits are varied according as they are wanted or not, or according as the supply of them is scarce or plentiful, so also it may be expected that the regulations regarding ametropia will be varied. In case there are more recruits to be had than are wanted, better qualities of vision may be insisted upon; in case the need is greater than the supply, inferior qualities of vision will have to be accepted. But obviously, when the standard for vision has to be reduced, the reduction should be confined as far as practicable to those parts of the army in which it will least interfere with the performance of the duties appertaining to them.

34. Character of Vision possessed by a Myope of $\frac{1}{24}$.—A person affected with M. $= \frac{1}{24}$, or nearly 1·75 D, sees all objects beyond two or three feet with more or less indistinctness. At the distance of 20 feet books on shelves, or other objects of like sizes, appear mixed up together owing to want of definition and reduplication of outlines, while, though at this distance, the figure of a man may be seen well enough, his features are not separately distinguishable. An acquaintance even is not recognised at this distance if the recognition depend upon peculiarity of feature, unless the light is very strong and happens to fall directly upon the face, though striking contrasts in uniform such as stripes on the sleeve, medals, differences in colour, or peculiarities of carriage and of movements of the body, are sufficiently obvious, even under moderate light. At a distance of 50 yards and upwards groups of five or six persons standing together before a moderately dark background cannot be readily separated from one another so as to admit of being counted with accuracy. Dark objects on a white ground, such as large black letters on a white notice board, appear lighter, and the white ground appears darker, than they really are, while the letters are so spread out that they are altogether indistinguishable at a distance at which an eye with normal vision can recognise the painted words without difficulty. More distant objects, such as the general features of a landscape, houses and persons among trees, are huddled together and converted into little else than general shadows with intermediate outlines. The nature of particular objects even of large size can only be made out when the accidental advantage of some sharply-marked contrast is afforded, such as is presented by a ship floating on water, by a building or a tree having the skyline as a background, or when a well-known object such as a horse is in movement on a road. Even this last object ceases to be distinguishable at a distance of seven or eight hundred yards if it be passing by a dark background such as a belt of trees. The want of clearness of view increases, and the power of recognition diminishes, in proportion as the intensity of light diminishes, so that on a day when the sun is obscured by cloud, and the light therefore comparatively dull, but not so dull as to interfere with the perception by normal vision, the power of distinguishing objects by the myope of $\frac{1}{24}$ and higher degrees is materially curtailed. The opening of the pupil to admit more rays of light obscures the view through greater diffusion of the peripheral rays. Still more difficult does it become for such myopes to distinguish particular objects after sundown, even when there is sufficient light for men with emmetropic vision to be able readily to perceive and recognise them.

It is true that such myopic persons have the compensating advantage of seeing minute objects near to their eyes clearly, and that they retain this power at periods of life when convex spectacles have become a matter of necessity to persons with emmetropic vision; but obviously this special power is of scarcely any advantage so far as military service is concerned.

The visual difficulties just now described have to be encountered by myopes when the atmosphere is of its ordinary clearness, and when only the intensity of light is diminished. Such difficulties are greatly aggravated when the atmosphere from any cause is not clear, as when there is fog, mist, or when rain or snow is falling. Under these conditions, the view of objects becomes more or less obscured, according to the amount of rain or watery vapour in the air, to all persons, however acute their power of sight may be; but in the case of the myope the obscurity is much augmented relatively to an emmetropic person from the effects of ray-diffusion. The increase of obscurity is in proportion to the increase in the degree of myopia. If two persons, one myopic, the other emmetropic, are looking at a misty landscape, the former sees it as if he were looking through a thicker veil than the latter. When the mist is only moderate in amount, permitting all the principal objects in a landscape embracing several miles to be distinguished by the emmetrope, although the foreground, middle distance, and distant hills may appear clouded and to have a general grey hue, the myope finds a difficulty in recognising many of the objects before him. The whole prospect appears lighter in colour, and the principal objects in it have their outlines less defined. This happens, although the degree of myopia may not exceed one dioptric. The surface of the hull of a ship at anchor, which appears dark to an emmetrope, is so mixed up with the water on which it floats, and the surface of the water with that of the ship, that both assume a nearer approach to uniformity of tint, and blend together more intimately. If the myope have a higher degree of myopia—a degree equivalent to two dioptrics for example—the most distant objects of the landscape disappear from his view altogether, while nearer objects are rendered more indistinct. The outlines of such an object as the ship just now mentioned are still more diffused, while perhaps the masts and rigging fade from sight altogether. If the myopia be still higher in degree, such as 4 D, even large objects in the foreground are quite confused; while such an object as the ship on the water, notwithstanding the strong difference in colour which really exists between them, becomes indistinguishable, is not only not recognised, but is not seen. It is mixed up with the general haze. The retinal images of the mist and rain, like the images of other objects, are diffused and mixed together, from the scattering of the rays attendant on the myopic formation of the eyes, and increase the general obscurity of the landscape presented to their view. Even suitable lenses, that would correct the myopic vision under other circumstances, fail to rectify the faulty vision in such weather, for the fog or mist clouds the glass, or the rain wets it and for the time destroys its translucency.

The injurious influence on eyesight just described of such a moderate degree of M. as $\frac{1}{24}$, or about 1·75 D, sufficiently indicates the objection to putting myopic officers or men on any duties, especially in the dusk of twilight or when the atmosphere is misty, the proper fulfilment of which depends either on an extensive range of clear vision and observation, or on keeping a sharp outlook as regards objects at any distance, which are neither very conspicuous from size or contrast of colour.

When the quantity of light is much lessened, as in twilight or dusk, the pupil of the myopic eye, in common with the pupils of all eyes, dilates in order to admit more of the rays of light proceeding from objects, and in this way to make up for their diminished illumination. The vision of the emmetrope is improved by these means notwithstanding the general obscurity, for the retinal impressions are amplified owing to the increased quantity of light admitted through the enlarged pupil. The vision of the myope, on the other hand, is on the whole rendered worse by the occurrence. A greater amount of light is equally admitted into the myopic eye, but the dilatation of the pupil at the same time unavoidably gives access to more peripheral rays. The retinal images in consequence are obscured by a greater number of circles of diffusion, these circles are more widely spread, and increased indistinctness of view is the result.

35. **Degrees of Myopia admissible when the Test-dots are held at 15 Feet.**—A myope with M. = $\frac{1}{32}$ or 1·25 D still sees objects mistily, but the difference between the degree of haziness and that of a myope with M. = $\frac{1}{23}$, or 1·75 D, is considerable. If the test-dots were ordered to be counted, *e.g.*, at 15 feet, myopes with

M. $= \frac{1}{30}$ would be just capable of admission, and of course all lower degrees of M. could pass the test; but myopes with M. $= \frac{1}{24}$ and upwards would be excluded.

A myopic eye of $\frac{1}{30}$ can read No. 2 Snellen at a distance of 2′, but not No. 3 Snellen at the full distance of 3′, can recognise No. 20 Snellen in good light at about 10′, showing V. $= \frac{1}{2}$; and has a distant point of distinct vision for No. 2 Snellen at $7\frac{1}{2}''$ with the 10″ convex lens before it.

36. **Degrees of Ametropia which exclude from Service in Continental Armies.**—In continental armies the degrees of ametropia which render men unfit for military service are always very high degrees. But it must be remembered that these armies are raised by conscription, and the degrees of ametropia which have been fixed for excluding from military service are those which are understood to cause total unfitness for military avocations, not merely such as unfit men from becoming reliable and good riflemen. The important point is not to be forgotten, too, that in armies raised by conscription, if a conscript is affected with a less degree of ametropia than the absolute disqualifying degree, but still one that unfits him for becoming a good rifleman, cavalry scout, or artillerist, he is simply drafted to some other part of the army in which his amount of ametropia will not interfere with the right performance of duties belonging to it. The system of the British Army, as already mentioned, does not arrange for distribution of men on the same principles.

37. **Short-sighted Men at Musketry Instruction.**—One of the regulations regarding musketry instruction provides that "short-sighted men may, when firing, wear spectacles" (Regulations for Musketry Instruction, 1884, par. 19, ch. 1., General Regulations, p. 11), and, as regards "Aiming Drill" (*op. cit.*, para. 77, p. 85), it is laid down that "short-sighted men should aim at distances according to the power of their eyesight; they may wear spectacles." The wording of this latter direction probably does not fully convey its meaning; for if short-sighted men be permitted to wear spectacles, and no ocular defect excepting short-sightedness exists, properly adjusted spectacles would place the short-sighted person concerned in the same condition as another person who is not short-sighted. Other conditions being normal, the power of sight of the myope, when corrected, would be the same up to the farthest distance as that of an emmetropic man. When spectacles are not worn, the range of accurate vision will be limited in the case of the myope by the degree of his myopia and the consequent distance up to which he can secure distinct definition of objects.

38. **Visual Range for Trained Soldiers.**—Trained soldiers at the annual course of musketry instruction fire at range practice at distances which vary between 150 and 800 yards. In order, therefore, that a man may have a fair chance of qualifying for a marksman, or for a first or second class shot, he must have sufficient visual power to enable him to see clearly an object of the size of the bull's-eye of the target used at the farthest distance named. The bull's-

eye is 3 feet in diameter, and at 800 yards would subtend a visual angle of 4′ 54″, no great demand on vision, provided the atmosphere is clear and the object is sufficiently illuminated.

39. **Trained Soldiers unable to see the Bull's-eye at 800 Yards.**—Special directions are given in the general regulations for musketry training with respect to soldiers who are certified by medical officers to be unable to see the bull's-eye at 800 yards' distance. Men who cannot see clearly the bull's-eye at the distance named are to fire at one or more of the range practices in the individual firing of the annual course of training according to their power of vision. It will no doubt devolve on medical officers to state what the power of vision is in each case concerned.

40. **Use of Spectacles by Soldiers in the Ranks not sanctioned.**—The use of spectacles by soldiers in the ranks, whether serving at home or on foreign stations, for the correction of ametropic defects of vision, is not sanctioned by any published regulation in the British Army. Special difficulties would be experienced if glasses were allowed to be worn in the English army as they are by parts of the troops of some continental armies. There would be the want of means under present circumstances of replacing them when injured or broken in many of the distant stations in which English troops are habitually employed; while, if the glasses were damaged or broken when the men were on active service out of Europe, there would frequently be almost insuperable difficulties in replacing them, and this would just be the time when they would be most urgently required. The education in respect to the use of such appliances and the habits of a large number of the men composing the ranks of the English army must also be taken into account. Moreover, though the spectacles might be perfect in correction, when dust, rain, condensed moisture, or other circumstances interfere with the transparency, and therefore with their utility, accoutred infantry soldiers carrying rifles, or mounted troopers, are too fettered to be in a position to remove these impediments as frequently as they occur, and, during the time they were thus obscured, the spectacles would cease to be of any advantage. These are probably the principal reasons which have prevented the use of spectacles from being sanctioned among men in the ranks of the army.

If the use of spectacles by men in the ranks should hereafter be sanctioned, arrangements will at the same time have to be made for enabling the men who wear them to replace them whenever they may happen to be lost or broken. Machine-made spectacles for correcting ordinary degrees of myopia and hypermetropia are now manufactured so cheaply, and in many instances answer their intended purposes so fully, that with proper examination and selection the cost alone would hardly be an impediment to their introduction among soldiers. The great difficulty to be overcome in their introduction would be the arrangements necessary for ensuring suitable glasses being always available on occasions of need.

41. **Range and Power of Vision necessary for Commissioned**

Officers in the Army.—The requirements for distinct vision appear to be even more imperative in officers than in private soldiers. They must look down whole lines of men, and see them with distinctness. They are required to observe distant objects and not unfrequently to give important directions according to the judgments they form of them. It is also of personal importance to combatant officers on taking the field that they should possess a normal range and power of vision, or at least a range not far short of normal range. An officer of the regiment in which I was serving during the Crimean war declared himself unable to take picket duty, because he could not distinguish an enemy from a friend at a short distance from him, particularly in twilight, and, on the matter being referred to a committee of medical officers, was reported unfit for service in the field in consequence of a high degree of short-sightedness; and during the same campaign it certainly once happened, if not more often, that an officer was taken prisoner by walking into the midst of a party of the enemy whom he failed to distinguish from his own troops owing to the same cause. I subsequently made a voyage with one officer who was taken prisoner under the same circumstances mentioned, and sent to Russia, and the high degree of his myopia was sufficiently obvious. An unfortunate English regimental surgeon in the Crimea who was affected with myopia failed to recognise a French sentry from a distance in front of the lines at which the sentry saw him but too plainly, and he lost his life in consequence.

42. **Loss of Sight of one Eye.**—Loss of sight of one eye from any cause, however good the sight of the other eye, totally disqualifies for an army commission. It is obvious that if a candidate were passed fit for a commission, notwithstanding loss of sight in one eye, he would not only be less efficient, but any injury interfering with or destroying sight in the remaining eye after he had entered the service would entirely disable him for further duty. Other considerations arise when the sight of one eye of an officer already serving in the army is lost, while the other remains effective; and consequently officers are occasionally to be met with, as well as men in the ranks, who only have the sight of one eye left. But their efficiency in various respects is nevertheless considerably lessened. (See Binocular and Monocular Vision, p. 2.)

43. **Declaration as to Sight by Candidates for Army Commission.**—Every candidate for a commission in the army now signs a declaration concerning his general state of health prior to undergoing physical examination, especially that his "vision is good with either eye (with or without the aid of glasses, as the case may be)." Remembering, however, that persons have very different views as to what constitutes "good vision," many knowing no other standard of quality than that of their own vision, it is obvious that an independent examination is necessary to ascertain the real quality of sight in each instance, or, at any rate, to determine that it is not below some definite authorised standard. The declaration has the advantage of being calculated to prevent a candidate submitting

himself to examination who has any serious defect of vision in either eye.

44. **Visual Acuteness required in Candidates for Commissions in the Line.**—The existing rule for the visual examination of candidates for commissions in the line is as follows:—Simple myopia or hypermetropia is not to be held a disqualifying condition. So long as these defects can be corrected by suitable glasses they are not to exclude from admission. The practice is that if the candidates for commissions can count the test-dots at the ordinary distances, with or without the aid of glasses, they are accepted for service so far as vision is concerned. The test-dots are used in the same manner as with men seeking enlistment in the ranks. Care should be taken that the examination is carried out strictly in accordance with the rules before described in all its details.*

45. **Use of Correcting Glasses at Visual Examinations.**—No rule has been published regarding the manner in which candidates for commissions are to employ glasses in the correction of visual defects. The responsibility regarding the point appears to rest with the examining medical officer. In some instances candidates are allowed to use the glasses with which they have provided themselves prior to the examination; in others they have been required to select the glasses which suited them from a number of pairs of spectacles placed on a table in the examination room.

This latter method of examination might be a convenient one to some examining surgeons, presuming the refractive powers of all the glasses to be marked upon them, and glasses only of such powers to be placed on the table as are suited for correcting the range of refractive defect which does not exclude candidates from admission into the military service. But manifestly the lenses ought to be single, not fixed in pairs as in ordinary spectacles, in order to meet cases in which the two eyes are dissimilar in their refraction, whether the difference between them be one merely of degree or a difference in kind of refraction.

46. **Decision as to Fitness for Service reserved in Special Cases.**—Although all candidates for commissions in the army are allowed

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* *Deception Practised at Visual Examinations.*—Attempts to impose upon examining surgeons may occasionally meet with success. Some years ago I was asked by the friends of a youth who was anxious to obtain a military career, but whose sight was defective in one eye, whether any likelihood existed of his being able to pass the physical examination for a commission. I found on examination that although V. was normal in the right eye, only quantitative V. existed in the left eye. I therefore said there was not the least chance of his passing the examination, as each eye would be subjected to tests separately. The next time I met him he was going through the course of study at Sandhurst. I inquired how he had contrived to get through the examination as to power of sight, and he at once showed me his plan of proceeding. When he was asked to count the test-dots with his right eye he did so easily, at the same time covering his left eye with his *left* hand. He was then told to count them with the other eye. In answer to this direction he covered the left eye, the same he had covered before, but this time with his *right* hand, and of course, as before, counted the dots without difficulty. He had changed hands but not eyes, and this he did so quickly and smartly, that the examiner, who may at the moment have been observing the test-dots to ascertain if the right number were stated, did not notice the feat of legerdemain which was being practised on him, and passed him as optically fit for service.

to use glasses when being tested as to power of sight, the military authorities retain the power of deciding in every instance of myopia or defective vision, according to its special characters, whether the candidate is to be declared visually fit or unfit for the military service.

47. Visual Qualification for Commissions in the Medical Staff.—In the "Schedule of Qualifications necessary for Candidates desirous of obtaining Commissions in the Army Medical Staff," it is ordered that a Board of Medical Officers must certify the candidate's "vision is sufficiently good to enable him to perform any surgical operation without the aid of glasses. A moderate degree of myopia will not be considered a disqualification, provided it does not necessitate the use of glasses during the performance of operations, and that no organic disease of the eyes exists."

The objection to dependence on the use of glasses for securing clear vision in the performance of surgical operations is a well founded one. Irrespective of the inconvenience which may occasionally arise from glasses falling off in the movements of the operator, they are constantly exposed to loss of transparency from condensed vapour upon them, or from becoming spotted by jets of blood.

So far as concerns the refractive defect of myopia mentioned in the schedule, it will not be difficult for a moderately myopic candidate to comply with the condition named, for the myopia must be of very high degree to necessitate the use of glasses in performing most surgical operations. With a myopia of 2·0 D, or $\frac{1}{20}$, a candidate of twenty-five years of age with normal power of accommodation, would have a range of clear vision for small objects from a distance of 20 inches to a point a little under 4 inches, without the aid of glasses, and indeed within this range named would see better without glasses than with them, though his vision for more distant objects would be very imperfect unless helped by suitable glasses. Even with a myopia of 2·50 D, or $\frac{1}{16}$, he would have a range of clear vision from a distance of 16 inches to a little over 3½ inches. But with a hypermetropia of 2·50 D, when, at the age named, only six dioptrics of accommodation would be available for work at near objects, even with the highest accommodatory effort a near point of distinct vision could only be obtained at a little under 7 inches. Short of that distance vision by the unaided eye must be more or less obscured; and as it is not possible to continue to exercise accommodation at its highest state of tension, but only about half of the 8·50 D of the accommodation belonging to the age named could be continuously employed, the nearest point of distinctness for prolonged vision would be removed to 20 inches distance. Under such circumstances attempts to distinguish minute structures of importance, probably confused by blood, to separate a small artery from an adjoining nerve for example, without the aid of suitable glasses, would be very embarrassing, and might lead to serious errors. It is therefore the hypermetropic eye which would meet with the most difficulty in operating without glasses, and this difficulty would increase with increase of age. If the hypermetropia were complicated by astigmatism, the difficulties of the operator would be considerably increased.

48. **Visual Acuteness required in Candidates for Commissions in the Royal Artillery and Royal Engineers.**—Candidates for admission into the Royal Military Academy at Woolwich fall under a special regulation. Since March, 1871, by order of H.R.H. the Field Marshal Commanding-in-Chief, these gentlemen have been required to show at their physical examination that they possess a range of vision which will enable them to see clearly the 2′ square bull's-eye at 900 yards. In order to decide that a candidate for admission into the Artillery or Engineers possesses this required qualification, the examining medical officer will have to ascertain that he can count the square regulation army test-dots at a distance of 22½ feet instead of the distance of 15 feet named in the instructions on the back of the card. If the order were applied to the circular bull's-eye 3 feet in diameter, the circular regulation test-dots in present use would have to be held at a distance of 15 feet in order to prove the candidate's power of seeing the bull's-eye at 900 yards. The candidates are permitted to use ordinary concave and convex spectacles at the examination.*

49. **Visual Acuteness required in Candidates for Commissions in the Royal Navy.**—Candidates for commissions in the Royal Navy are not considered eligible who are subjects of any degrees of myopia or hypermetropia. They are required to have visual power sufficient to enable them to see Snellen's test-types at the full distances. Exceptions are, however, made in some special cases under particular circumstances, but the discretionary margin allowed is very limited. It would manifestly be unnecessary to apply the same visual tests as rigidly to naval chaplains and clerks as to navigating officers.

50. **Quality of Sight for Special Course of Instruction in the School of Musketry.**—Officers and non-commissioned officers who desire to attend the special rifle instruction given at the School of Musketry, must be certified by a medical officer to be free from defective eyesight. The term "defective eyesight" in the musketry regulations, implies that neither the signal flags or discs used at target practice, nor the bull's-eye 3 feet in diameter, can be seen at a distance of 800 yards. But in testing vision in accordance with this rule, permission is given that spectacles, but not field glasses, may be used. In order to ascertain whether a man can see the 3′ bull's-eye at 800 yards, the test-dots must be held for counting at a distance of 13 feet 4 inches—for 3′ : 800 yards :: ⅕th of an inch : 13⅓ feet. If then the test-dots can be readily counted

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* I have been informed by Surgeon-Major Evatt, M.D., Surgeon to the Royal Military Academy at Woolwich (11 Feb. 1884), that candidates rejected on account of defective eyesight at the physical examination can nevertheless go up for the literary examination, and if successful at it can appeal to a Special Board of Medical Officers in London as regards their eyesight. But no instance of such an appeal had occurred during his tenure of the Surgeoncy at the Academy, which had lasted several years.

at the distance named, the 3′ bull's-eye, other things being alike, can be seen at 800 yards.

51. **Disease of some of the posterior Parts of the Eye.**—When the ocular examination of the recruit or soldier leads to a suspicion that he labours under impaired vision owing to deeply seated disease of the eye, there is only one way of determining the correctness or incorrectness of the suspicion, and that is by ophthalmoscopic examination. A description of the method of employing the ophthalmoscope, as well as of the other steps to be taken, for establishing a correct diagnosis of the different morbid states of the posterior parts of the eye, forms a portion of the subjects treated upon in all systematic works on diseases of the eye.

52. **Impaired Vision, or Blindness, of one Eye in a Trained Soldier.**—It has been mentioned with regard to a recruit that any important visual defect in either eye renders the man unfit to engage for service as a soldier. The rule is different with regard to men who are already serving in the ranks. Impaired visual power, or total loss of vision of one eye, if the other eye be efficient, is not held to be a cause of unfitness for further military service. This rule is laid down in War Office Circular, No. 874, of the 17th August, 1864, in the following terms: "No soldier shall be discharged for the loss of one eye only, whether it be the right or the left; but if a soldier shall have lost one eye by a wound in action, or by the effects of service, and shall receive other wounds or injuries in action, or be otherwise so disabled as to render his discharge necessary, the loss of an eye shall be taken into consideration in fixing the pension at such a rate as his combined wounds or disabilities may entitle him to receive."

53. **Aiming with the Left Eye.**—If a soldier after enlistment is found to have a defect of vision of the right eye, which has not been previously detected, and it is found to incapacitate him for using his rifle from his right shoulder, or if the right eye of a soldier becomes disabled by disease or injury, he is permitted by the musketry regulations under certain rules to fire from the left shoulder—thus using his left eye for sighting the objects aimed at.

This permission is never granted excepting under certificate from a medical officer that the soldier is labouring under defective vision of the right eye. Now that skirmishing and independent firing are so much more employed than firing in close order, it is of less consequence that a man's mode of firing differs in the respect named from that of the other men of his company. Moreover, the permission to aim with the left eye is only turned to practical account at target practice, or when firing with ball cartridge.

54. **Assumed Blindness of one Eye.**—Blindness of the right eye is not unfrequently simulated in foreign armies to escape conscription, but English soldiers very rarely make pretence of blindness of one eye, because it is well known among them that loss of sight of one eye does not incapacitate for further military service. Should, however, blindness of one eye be alleged to exist, and no objective signs to warrant the assertion be obvious, so that a sus-

picion of simulation be excited, there are various tests which may be resorted to for determining whether the suspicion is well grounded or not.

In the first place, the observation of the surgeon may be directed to the supposed blind eye. In complete blindness of one eye, the pupil is partially dilated owing to the absence of all reflex stimulus from the insensible retina. If then, on trial, the iris is found not to contract when the alleged blind eye has been shaded by the hand of the surgeon and then suddenly subjected to the admission of strong light, but is found to contract when the retina of the other eye is exposed to sudden access of light under similar conditions, it is evident that the alleged existence of blindness is real; on the other hand, if the iris of the alleged blind eye does contract when its retina is exposed to sudden light, while the other eye is kept closed, there may be a considerable amount of amblyopia, but there cannot be complete amaurosis. If the iris of the alleged blind eye do not answer to the stimulus of light, either when its own retina or that of the other eye is excited, the alleged blindness may or may not exist; the observation only proves that there is paralysis of the iris, and this may be the result either of natural causes or may be artificially induced.

The effect of covering the alleged blind eye and then of suddenly exposing it to light, on the other, or acknowledged seeing eye, may next be observed. When the two eyes are in a normal condition, the effect of shading one of them from light is to produce a slight increase in the size of the pupil of the other eye; on removing the shade and exposing the eye suddenly to light, a slight decrease in the size of the pupil of the eye that has not been shaded may be noticed. If one eye be blind, neither shading nor uncovering this blind eye will produce any change in the dimensions of the pupil of the other eye.

But the most effective means for unmasking an attempt at deception of this sort is Gräefe's prism test. If a prism of 12° or so be held with its base upwards or downwards before the eye in which visual power is acknowledged to be retained, and the person who is subjected to the test on being asked what effect it has on his sight, states that the glass in front of his eye causes him to see double, the simulation is proved, for diplopia could only result by both eyes seeing. If the person under examination is educated, and a page of print is placed before him, while the prism is placed in front of his seeing eye with its base upwards, and he is then unable to read without great difficulty, it is another proof that he is seeing with both eyes, and that his reading power is interfered with from the images of the print overlapping; if he really had only monocular vision, he would see the print with the prism as well as he did without it, though it would be a little altered in its apparent position. Again, if the base of the prism be turned horizontally inwards, and the eyes then squint, it is proved that an effort is being made to prevent double vision, and that, therefore, the assertion of blindness of one eye is untrue. By getting the person to read some of Snellen's test-types, and to describe first one of the two images and then the other, and by varying the sizes of the objects presented, the surgeon may arrive at a conclusion as to whether any amblyopia exists or not in the alleged blind eye, and if it does exist, may even ascertain its degree.

Case.—The following case, taken from the records at Netley, will serve to illustrate the application of this test. Private T. F., 84th regiment, was invalided in 1866 from Malta, and admitted at Netley, under Amaurosis. His condition at Netley he stated to be: right eye quite blind, no perception of light; left eye, reads No. 4 Snellen at 3″, counts fingers at 3′. No ocular abnormality was visible by ordinary or under ophthalmoscopic examination. The left eye was kept bandaged for a couple of days, on the plea of resting the eye, but really to observe whether he could guide his movements by the right (alleged totally blind) eye. While thus bandaged he was reported to have been seen reading, or apparently reading a book. I then tried the prism test, and the man described two images of a single object, a lead pencil, held at a distance of about 4′ from him, together with the movement of one round the other as the prism was made to revolve before his left (acknowledged seeing) eye. The imposture being thus proved, the man was discharged to duty at his depôt.

If a prism is not available, the table of 20 feet coloured types on a black ground, in Snellen's book of test-types, may be turned to account for a similar purpose. Placing the person under observation at the farthest distance at which he can read the types with both eyes open, a piece of coloured glass, either red or green glass, is placed in front of the eye acknowledged to be sound, and he is asked if he can still read the letters. If green glass is before the eye, and he is able to read the red letters through it, or if he can read the row of green letters through the red glass, it is obvious that he is reading them with the alleged unsound eye. As the coloured glass causes the types of complementary colour to fade or disappear altogether from view, the sound eye under the conditions described cannot read them. If scales of coloured types of various sizes were at command, not only the fact of the uncovered eye seeing, but its degree of acuteness of vision, might also be ascertained by one and the same experiment.

The stereoscope has been used for detecting simulated blindness of one eye, and is still more puzzling to one who is not acquainted with its effects. The particulars of a case were related to me in which imposture by a foreign officer who simulated blindness of one eye as a result of field service was fully detected by its means, and in this instance the use of a prism, owing to the intelligence of the person examined by it, and his knowledge of the effects of prisms, had failed to prove the deception. Indeed it is hardly possible for a person who is not blind on one side to answer the stereoscopic tests as if one eye were blind, provided the experiment is fairly performed. But the surgeon must be on his guard that the person under examination does not close the eye which is alleged to be blind while the objects placed in the stereoscope are exposed to his view. The eyes must be watched during the examination. The stereoscopic objects should be specially prepared. Series of lines, different in colour, red and blue for example, so arranged that in the combined image they cross each other, have been suggested by Helmholtz for the purpose. When both eyes are sensible to light, the red and blue lines are seen constantly changing places with each other, and it is not possible to say by which eye either coloured lines are seen. A person blind of one eye will see the lines of one colour only. Two printed paragraphs, equal in size and similar in character, but differing in parts of the text, may be placed on the stereoscopic slide. A person regarding the slide with both eyes through the stereoscope will not be able to read the portions where the texts differ, for the print of one side will be mixed up with the print of the other in constant interchange so as to make reading impracticable. A person who does not see with one of his eyes will read easily the print presented to the seeing eye. Figures in endless varieties of shapes and colours may be employed in a similar manner; so that no simulator who is capable of seeing the objects presented to him on the stereoscopic slides with both his eyes, when describing what he sees, can help including those parts which could only be visible to him through the agency of his pretended blind eye, unless he succeeds in temporarily closing it for the purpose of excluding its view.

Staff Surgeon Dr. Burchardt, of Berlin, invented a portable stereoscope, of very ingenious construction, for the practical diagnosis of simulation of blindness or amblyopia of one eye.[*] The test-objects supplied with the apparatus are very effective. The prisms are so arranged that at the same time that the person under examination is looking through them at the test-objects, the examiner can look through them and obtain a magnified view of the eyes of the person he is examining. He can thus ascertain that neither of the eyes of the supposed simulator is closed even for a second during the application of the tests.

55. **Assumed extreme defective Vision of both Eyes.**—Supposing a soldier maintains that he cannot see clearly the bull's-eye at any range, or only within a very limited range; that no description of lens improves his vision; while no cause for the alleged disability can be discovered, but, on the contrary, both eyes appear to be of normal visual power, can it be proved that he really does see clearly enough for duty? To a certain extent the surgeon must be guided in such a case by circumstantial evidence and observation. A cross-examination, instituted with ordinary judgment, will usually expose the attempt at fraud. But in such cases the lenses can generally be turned to important use; with the convex spectacles before his eyes, a trickster will most certainly become confused, and will either see types or dots at distances which show that his vision is normal for distant objects, or he will overstate his case by giving only negative replies, saying that he cannot see at all at any distance. When this last-named position is maintained by a simulator, the surgeon can only hope to expose the deception by contriving to obtain positive evidence showing that the man's statements are untrue. This plan was adopted in the following case:

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[*] Praktische Diagnostik der Simulationen von Gefuhlslähmung von Schwerhörigkeit und von Schwachsichtigkeit, herausgegeben von Dr. Max Burchardt, Oberstabsarzt 2 Cl. u. Privat Docent. Berlin, 1875. Verlag der Gutmann'schen Buchhandlung. Otto Keslin.

Case.—Private G. McA., æt. 19, was sent after enlistment to the depôt at Parkhurst. Subsequently to his arrival there he declared his sight to be extremely defective, and he was reported to be unable to learn his drill on this account. He was then examined by a medical board at Portsmouth. The board not finding anything to explain the alleged condition sent him back to Parkhurst. The surgeon in charge again after some time reported his inability to serve as a soldier on account of defective sight, and he was ordered to Netley for observations. At Netley according to statement 100 Snellen could not be seen beyond 2½′; fingers could not be counted farther off than 1′, and hardly at that distance. Nothing abnormal could be detected in either eye by ophthalmoscopic or ordinary examination. When tried with lenses all replies were negative; he persisted in saying that he could see nothing through them at any distance. The extreme degree of amblyopia complained of was inconsistent with many of the man's observed actions, but it was difficult to get a positive proof sufficient to convince others of the deception, and a trap was therefore laid for him. While walking he was suddenly told by a serjeant in the presence of a witness to pick up a pin which had been purposely placed a little way off on the floor before him. The man being taken unawares at once stooped and picked it up. He was sent back to the depôt and made no further complaint of weak sight.

If the man admits that he can see objects of known dimensions, the hands and figures of a clock for example, up to some particular distance, the surgeon can notice whether, after varied changes in position of the object, he always returns to the same distance as his limit of clear vision.

If the man is able to read, the distance at which a given type of Snellen's standard is read may be noted, and observation made whether he reads the larger types, illuminations and other conditions being alike, at proportionate distances. If he should state he is not able to do so, and he still maintains that neither concave nor convex glasses make distant objects clearer, and there is no evidence of the presence of astigmatism, it is obvious that he is trying to deceive. Where there is a command of lenses of many varieties of focal range, the demonstration that he is simulating his alleged defect of sight is comparatively easy.

I would not, however, wish it to be inferred from the above remarks, that I believe attempts at fraud, in respect to defective vision, are frequently to be met with among soldiers in the ranks. On the contrary, my experience leads me to believe that in the greater number of instances which have been suspected to be instances of deception, real disabilities have existed, though their true natures have not been ascertained. The patients have been supposed to be malingering because sufficient time and attention have not been devoted to the elucidation of their cases, or because the determination of the existence of the particular defective conditions of sight under which they were labouring was not included in the surgeon's range of diagnosis.

APPENDIX.

EXTRACTS FROM MUSKETRY AND OTHER REGULATIONS CONCERNING EYESIGHT WHICH AFFECT MEDICAL OFFICERS, WITH NOTES ON SOME OTHER MATTERS REFERRED TO IN THE BODY OF THE WORK.

Quality of Eyesight for Musketry Practice.—Spectacles.—Good Sight and Proficiency in Shooting.—Classification of Firing Distances.—Aiming Drill.—Judging Distance Drill.—Attendance of Medical Officers at Target Practice.—Eyesight of Officers and Serjeants at School of Musketry.—Range of Vision for the Royal Military Academy at Woolwich.—Militia Regulations regarding Vision.—Admiralty Instructions concerning Eyesight.—Rules in the German Navy.—Degrees of Visual Deficiency, Myopia, &c., which exclude from Military Service in Foreign Armies.

Quality of Eyesight for Musketry Practice.—"No soldier is on any account to be exempted from any musketry training on the plea of alleged bad sight, or on any plea which, if valid, would tend to prove him unfit for service. When the medical officer certifies that a man cannot see up to 800 yards, he must fire, according to his powers of vision at one or more of the 'range practices' in the individual firing of the annual course, but not more than ten rounds at each distance, and his points must be included in the totals from which the merit of the shooting is calculated."—(Regs. for Musketry Instruction, 1884, par. 19, p. 11.)

Firing from the Left Shoulder.—"If the medical officer certifies that a man has defective vision of the right eye, he may fire from the left shoulder."—(Regs. *cit.*, p. 11.)

Spectacles.—"Short-sighted men may, when firing, wear spectacles."—(Regs. for Musketry Instruction, 1884. Regs. *cit.*, p. 11.)

Good Sight and Proficiency in Shooting.—"It cannot be too strongly impressed upon the recruit that any man who has no defect in his sight can be made a fairly good shot, and that no perfection he may have attained in other parts of his drill can, when on service, remedy any want of proficiency in shooting."—(Regs. *cit.*, par. 24, Ch. II, p. 15.)

Classification of Firing Distances.—"The firing distances in musketry practice are sometimes classified as follows:—Up to 400 yards 'short ranges;' from 400 to 900 yards, 'medium ranges;' from 900 to 1700 yards, 'long ranges;' and from 1700 to 3100 yards, the extreme range of the rifle, 'extreme ranges.'"—(Regs. *cit.*, par. 45, Ch. II, p. 22.)

Aiming Drill.—"Aim must be taken along the bottom of the notch, or the top of the centre white line of the back-sight, and the tip of the foresight to the centre of the mark aimed at."

"The eye must be fixed on the mark aimed at, and not on the foresight."

"In taking aim the left eye must be closed. If a recruit is not able to do this at first, he will soon succeed by tying a handkerchief over his left eye."

"It cannot be too strongly impressed on every man, that to shoot well at long ranges, he must train and strengthen his eye by looking at small objects at long distances. Short-sighted men should aim at distances according to the power of their eyesight; they may wear spectacles."—(Regs. *cit.*, pp. 83-85, par. 77.)

Judging Distance Drill.—"Instructors must bear in mind that the eyesight of different men varies considerably, and that consequently they must not expect that the observations and answers of every man will be the same."—(Regs. *cit.*, p. 88, par. 80.)

Attendance of Medical Officers at Target Practice.—"The attendance of medical officers at target practice under ordinary circumstances is unnecessary, but the name and address of a medical officer to whom application would be made in case of accidents, is to be communicated to all officers in charge of parties proceeding to target practice; and that officer is not to be absent from his quarters or hospital during the period the target practice is being carried on. Should exceptional circumstances arise which would appear to render expedient the presence of a medical officer on a range, the general or other officer commanding may, after consulting the principal medical officer, direct the attendance of one when necessary. The principal medical officer is to report all cases of this nature for the information of the director-general of the Army Medical Department, in order that timely provision may be made for the performance of the duties of the medical officer so employed."—(Regs. *cit.*, par. 91, p. 101.)

Eyesight of Officers and Serjeants at the Courses of Instruction in the School of Musketry.—"Officers and serjeants must have previously gone through a recruit's course; those with defective eyesight, *i.e.*, who are not able at 800 yards to see signal flags or discs, or a bull's-eye 3 feet in diameter, are on no account to be allowed to attend a course."

"In the test for vision, spectacles, but not field-glasses, may be used."

"Spectacles only, not eye-glasses, will be permitted to be worn at target practice at the School of Musketry."—(Regs. *cit.*, par. 181, p. 157.)

EXTRACT FROM "REGULATIONS TO BE OBSERVED BY THE MEDICAL OFFICER APPOINTED TO EXAMINE CANDIDATES FOR ADMISSION INTO THE ROYAL MILITARY ACADEMY AT WOOLWICH."

"*Range of Vision.*—Effective and long range of sight being preeminently requisite to be possessed by officers of Royal Artillery and Royal Engineers, all candidates for admission into these services must possess a power and range of vision which will enable them to see clearly the centre on an ordinary target at 900 yards."

"A candidate may be permitted the use of ordinary concave and convex lenses, and his range of vision may be tested by the ordinary test-dot card, held 22½ feet from him."

"He should be placed with his back to the window or point from which the rays of light fall upon the card, and care should be taken that full light is thrown upon the latter during the examination."

(Instructions issued by Director-General Sir G. Logan, K.C.B., dated 17th February, 1871.)

Quality of Sight of Right Eye necessary for Militia Recruits.—It is laid down in the "Regulations for the Militia, War Office, 1883," as regards the medical examination of recruits (Part I, sect. 2, page 32), that one of the principal points to be attended to is, "that his (the recruit's) vision is good, or at least sufficiently good to enable him with his right eye to discern objects clearly at not less than 300 yards." No particular size of object is specified in these regulations, nor is any visual limit mentioned as regards the left eye.

Quality of Vision necessary for Officers and Men of the Royal Navy and Royal Marines.—The following directions to medical officers in regard to the examination of the quality of vision possessed by men or boys seeking admission into the Naval Service or into the Royal Marines are laid down in the "Queen's Regulations and Admiralty Instructions (1879)." The medical officer is ordered to observe whether the person's eyesight is defective, and if it should be so to such an extent as might, in the opinion of the examining officer, disqualify him for the efficient discharge of the duties that would devolve on him, he is to report him unfit for the service. He is further instructed (par. 1074) that "the eyes should be clear, intelligent, expressive of health, and the eyesight good." In the succeeding "paragraph of the Instructions" (par. 1075), it is laid down that "persons of whatever class or age, who are found to be labouring under certain physical defects, are to be considered unfit for Her Majesty's Service, and among these defects is mentioned "blindness or defective vision in one or both eyes." The following direction also occurs in the paragraph of the regulations:—"Whenever test-types are supplied, the power of vision of each eye separately, as well as together, is to be ascertained; but before finally rejecting a person who has failed to read the types, he is to be tested with objects familiar to him, and at distances corresponding to the sizes of the objects, as the inability occasionally arises from other 'causes than defective' sight. When the sight is found defective, the particulars are to be recorded in the register of physical examination when required to be kept, how far short of the normal distances given in the test-types could the letters or figures be seen, and where one is more defective than the other, the limit of good vision of each eye is to be noted."

It is all the more important that naval officers and seamen should possess normal acuteness of vision, inasmuch as the use of correcting glasses is less admissible under the conditions of sea life than it is among officers and men engaged in ordinary military duties on land.

Rules for Determining Visual Competency in the German Navy.—The fitness of candidates in the Navy of Germany is determined by the degree of visual acuteness, and the capability of its correction by suitable spectacles in case it is below the normal standard. The Imperial Admiralty Orders (26th June, 1872) are to the following effect:—

1. The acuteness of vision is to be tested by Snellen's test-types. When the types can be read at the denominated distances it is to be considered normal, or = 1. The certificate must state clearly the result of this examination.
2. If the acuteness of vision be not normal, the surgeon must determine by ophthalmoscopic examination whether there is any organic disease of the inner parts of the eye. If there be, the candidate is to be considered unfit.
3. In the absence of organic disease of the eye, the following limits are to be adhered to:—
   - (*a.*) Candidates who recognise Snellen's types at $\frac{3}{4}$ of the denominated distance, *i.e.*, whose visual acuteness is = $\frac{3}{4}$, are to be considered fit for the naval service.
   - (*b.*) Candidates who recognise the types at distances between $\frac{3}{4}$ and $\frac{1}{2}$ of the normal distance, can be admitted, provided it is proved, by the application of spectacles, that their diminished visual power is perfectly corrected by their help.
   - (*c.*) Candidates whose visual power is only $\frac{1}{2}$ or less, are to be considered unfit for the naval service.

Degrees of Myopia, Deficiency of Visual Acuteness, &c., which exclude from Military Service in Foreign Armies.—The degrees of ametropia and amblyopia which exclude men from military service, or which exclude from service in particular parts of foreign armies, vary in different countries. They have been considerably modified of late years, and the rules shown in the second edition of this Manual, at pages 79 and 80, are now altered in many particulars. In some countries the rules regarding the degrees of the disqualifying defects, and also regarding the methods by which they are to be determined, are now laid down with much minuteness and precision. A study of the various regulations regarding visual defects and the modes of testing them, will be found to be very instructive. I have obtained copies of the most recent orders on these subjects in the principal armies of Europe, and in collecting them, Dr. Gori, Lector on Military Surgery and Hygiene in the University of Amsterdam, has afforded me valuable assistance.

Holland.—In Holland, Dr. Gori informs me, the Royal Act of November, 1883, decrees that M. = 2·5 D ($\frac{1}{15}$″) and upwards of the right eye in case the left eye is normal, and 7 D ($\frac{1}{6}$″) and upwards of the left eye in case the right eye is normal, renders a conscript unfit for service. The degree of M. is to be determined after mydriasis by atropine (homatropini hydrobrom. 2 per cent.), or by a refraction ophthalmoscope.

H. (total hypermetropia) = 6·0 D ($\frac{1}{6.66}$″) of right eye, in case the left eye is normal, and H. = 9·0 D ($\frac{1}{4·50}$″), or higher of the left eye in case the right eye is normal, also unfit for military service.

Ast. to such an amount that V. (visual acuteness) is reduced to less than $\frac{1}{5}$th in the right eye, the left being normal; or to less than $\frac{1}{20}$th in the left eye, the right eye being normal; entails unfitness for service in the army.

The rules are different for the volunteers of the military service. By the Act already quoted, volunteers using portable firearms must have V. (visual acuteness), without glasses, not less than $\frac{3}{4}$ths for the right eye, or $\frac{1}{2}$ for the left eye.

In case volunteers cannot fulfil the above requirement, owing to M. or H., they are admissible for service, if under 20 years of age, with M. = 1 D, or if over that age with M. = 1·5 D.; and with Hm. = 1·0 D, if under 20 years of age, and with Hm. = 2·0 D if beyond that age; provided that V. after correction by glasses is rendered distinctly = 1.

Medical cadets and candidates for army commissions who do not require acute distant vision are admissible if V. of one eye is not less than $\frac{3}{4}$ths, and of the other not less than $\frac{1}{2}$; or with V. of one eye equal to 1, with V. not below $\frac{1}{3}$rd of the other. In case of M. being the cause of the deficiency of V., medical cadets and candidates are admissible with M. = 3·0 D, or in case of H. being the cause, with H. not exceeding 2·0 D, provided V. is rendered = 1 by correction with glasses.

France.—In accordance with the instructions of the French Army Sanitary Council (Conseil de Santé des Armées), of 27th February, 1877, on the diseases or faults of conformation which unfit for military service, whatever the nature of the lesion may be, if it reduces V. to $\frac{1}{4}$th in the two eyes, or the right eye, or to $\frac{1}{12}$th in the left eye, or causes a diminution of about a half of the temporal angle of the field of vision, it renders the subject unfit for military service in the French army, unless, being the result of simply refractive defect, it can be corrected by glasses.

M., however, higher than 6·0 D ($\frac{1}{6\cdot66}''$), or complicated with muscular or accommodatory insufficiency, or with lesion of the ocular fundus, renders the subject of it unfit for service in the army. In the auxiliary service, M. between 6·0 D and 9·0 D ($\frac{1}{6\cdot66}''$ and $\frac{1}{4\cdot50}''$) is a cause of unfitness. The degree of M. must be determined by the optometer or by the ophthalmoscope.

H. renders unfit for service whenever it causes V. to be below $\frac{1}{4}$th in the right, or $\frac{1}{12}$th in the left eye. The determination of H. suffices; it is not necessary to specify the degree. The upright image of the fundus must be clearly visible, without dilatation of the pupil, by the aid of an ophthalmoscopic mirror at a distance of from 4 to 6 inches from the eye. In the auxiliary service H. which lowers V. below $\frac{1}{4}$th in a cause of unfitness, even though capable of correction by glasses.

Ast., like H., renders unfit for service whenever it causes V. to be below $\frac{1}{4}$th is the right, and $\frac{1}{12}$th in the left eye.

Germany.—In the German army a reduction of V. to $\frac{1}{4}$th, or below, causes permanent unfitness for military service in recruits; reduction of V. in both eyes to $\frac{1}{2}$, or less, but not as low as $\frac{1}{4}$th, allows recruits to be conditionally fit. M., when the distant point of the better eye is 0·15 m. (6 in.), or less, even though V. is normal at, and within this distance, renders recruits permanently unfit; M., with a distant point of more than 0·15 m., when V. after correction by glasses is more than half normal V., allows conditional fitness. Blindness of either eye is a cause of unfitness. Examination of V. in the recruiting service is as a rule to be by sight-tests, and Snellen's test-types are to be used till further orders. The results are to be expressed as regards V. in non-reduced figures ($\frac{10}{20}$ or $\frac{20}{20}$, not $\frac{1}{2}$ or 1).

As regards drilled soldiers, and men entitled to pension, reduction of V. in both eyes, if less than $\frac{1}{2}$, but more than $\frac{1}{4}$, of normal V., causes unfitness for field service; reduction of V. in the better of the two eyes to $\frac{1}{4}$ or less, causes also unfitness both for field and garrison service. Blindness of one eye causes also unfitness for field and garrison service.

No special rules are laid down as regards H. or Ast.

A War Ministry Order of July 15, 1881, makes known to medical officers that garrison-hospitals can be supplied with bi-concave or bi-convex spectacles for troops of the infantry, and spectacles with thread-covered steel frames for mounted troops, in a case, at $2\frac{1}{2}$ marks, or with postage 2·9 marks (about 3 shillings).

Italy.—The Royal Decree of the 26th of September, 1881, by which the previous list of infirmities exempting from military service were modified, rules that reduction of V. to $\frac{1}{3}$rd of the normal in the right eye; or to $\frac{1}{12}$th in the left eye, although V. in the right eye is up to the normal; if caused by organic changes or incurable disorders of the globe of the eye incapacitates for military service in the army of Italy. The existence and degrees of the defects must be established in a military hospital, must be recognised to be irremediable, and their nature must be specified, by a medical officer skilled in their diagnosis. By normal vision is understood the V. which permits objects to be distinguished under a visual angle not larger than 5′.

M. = 6·0 D $\left(\frac{1}{6\cdot6}''\right)$, or higher in the right eye, when accommodation is paralysed, incapacitates for military service.

Hm., such that with Ac. intact, and with the naked eye, there is not the power, under binocular vision, and at a distance of 0·30 m. (12 inches), to read printed characters of one millimetre in height, or to distinguish signs and objects of like dimensions; and that, with Ac. paralysed (total H.), amounts to 6·0 D in the right eye, exempts from military service.

Ast., such that V. in the right eye is reduced below $\frac{1}{3}$rd of normal V., also renders unfit for military service.

The existence and degrees of the refractive defects above mentioned must be certified in a military hospital after employing all the scientific means available, including ophthalmoscopic observation and, when needed, atropinisation.

As regards refractive defect, whatever may be its degree, if the left eye only is involved, it does not cause exemption from military service.

Austria.—The Austrian Recruiting Regulations of 1883 ("Instruktion zur aerztlichen Untersuchung der Wehrpflichtigen," Wien, 1883) give more precise directions as regards visual limits of fitness for military service than previous regulations on the subject. The necessary visual power (V.) which was before at the discretion of individual examiners, is fixed by them. It is mentioned in them that Snellen's types and objects, metrically numbered, have been introduced as sight-tests.

Reduction of V., but leaving more than one-half of normal V., does not incapacitate men for military service who are fit in other respects; reduction of V., but leaving more than ½ normal V. in the right eye, accompanied by reduction of V. to less than ½, or even to ¼th of normal V. in the left eye, incapacitates for general military service, but does not incapacitate for the Purveying and Clothing Departments and certain other portions of the army; reduction of V. to less than ½ in the better of the two eyes incapacitates for military service, but only after subsequent confirmation.

M. with a distant point of distinct V. at 12 inches from the eye, or beyond, does not cause unfitness for military service. M. with a distant point limited to 8 inches, if V. is good, though rendering unfit for general military service, does not incapacitate for service as medical officers, dispensers, in the clothing and administrative Departments, or as one-year volunteers. M. with a far point of 12 inches or less, if the man is able to read printed letters, or recognise figures of ⅓rd of a Vienna line in height and breadth at any distance from the eye when wearing concave 4-inch spectacles, determines unfitness for military service. If the man is able to read the test-objects under these conditions, he gives a positive proof that he is myopic beyond the limit of fitness, *i.e.*, beyond $\frac{1}{12}$th. If, although myopic, the man cannot read the print with the $-4'$ spectacles, he is to be sent to a military hospital for further scientific examination.

H. of such a degree that the man is able to read printed letters, or recognise other characters of 1 Vienna line in height, and of corresponding breadth at a distance of more than 12 inches from the eye when wearing $+6''$ spectacles unfits for service. Experience has proved that hypermetropic persons can comply with this test only when their H. is above ⅛th. If the hypermetrope cannot satisfy this test, further special examination is to be made at a military hospital. If H. is not so high in degree as ⅛th, it does not cause unfitness for military service.

Strabismus affecting either eye, if its central visual power is less than ½ of normal V., determines unfitness; strabismus affecting the left eye, if its visual power is more than ½ of normal V., does not cause unfitness for military service.

Belgium.—The latest Belgian regulations determine that reduction of V. in the right eye to ⅓rd of normal V. causes exemption from military service. Reduction of V. even below this limit in the left eye, by itself, does not cause exemption. Blindness of either eye causes unfitness for military service in the Belgian army.

M. of right eye, after paralysis of Ac., = 6·0 D ($\frac{1}{6\cdot66}''$) or above causes unfitness for military service. M. of even higher degree, in the left eye, does not by itself warrant exemption from service.

H. of right eye, after paralysis of Ac., = 6·0 D or above, causes unfitness for military service. H. of even higher degree in the left eye does not by itself warrant exemption from service.

Strabismus, with considerable contraction of the visual field, exempts from military service.

Switzerland.—The Swiss Army Regulations lay down the rules that the minimum of V. for the artillery is 1; for the infantry is $\frac{2}{5}$ths; and for all other troops is $\frac{1}{2}$ of normal V. All men in whom deficiency of V. may be corrected by ordinary + or — spherical glasses, and brought to a standard of $\frac{1}{2}$ up to normal V., are ruled to be fit for military service. They are permitted to wear spectacles. V. less than $\frac{1}{2}$ incapacitates for service, excepting as regards medical officers, in whom V. = $\frac{1}{3}$ is tolerated. Whenever V. in one eye is normal, V. in the other may be as low as $\frac{1}{8}$th; but, unless the eye with normal V. is the right eye, such men cannot be employed as riflemen.

Either M. or H. of higher degree than 4·0 D ($\frac{1}{10}$ inch), excludes from service in infantry or cavalry, even although it admits of correction by glasses.

Ast. is judged under the general rules for V.

Denmark.—The rules in the Danish army are the following:—

V. below $\frac{1}{5}$th ($\frac{20}{100}$ Snellen) incapacitates for military service.

M. up to $\frac{1}{18}$ (2·25 D) for combatants, and from $\frac{1}{16}$ to $\frac{1}{8}$ (2·50 D to 5·00 D) for other troops, does not incapacitate for military service; above $\frac{1}{8}$th (5·00 D) unfits for service.

H. up to $\frac{1}{9}$ (4·50 D) for combatants, above this degree for other troops, incapacitates for military service.

Ast. is judged by the standard of visual acuteness.

Spain and Portugal.—In the Portuguese army, M. of such a degree that the man can read or distinguish small objects at a distance of 0·25 m. (10 in.) with glasses of — 8·0 D, concave 5 in. or higher, and can see distant objects through glasses of — 7·0 D, concave 6 in., unfits for military service. In the Spanish army M., characterised by the possibility of reading small printed characters at a distance of 0·35 m. (14 in.) with glasses of —6·0 D, concave 6·66 in., and being unable to distinguish them with —2·0 D, concave 20 in., exempts from military service. No precise rules appear to be laid down as regards H. or Ast. in the Regulations of either the Spanish or Portuguese armies.

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